EPA
United States
Environmental Protection
Agency

Development Document for Proposed Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Industry Point Source Category

United States Environmental Protection Agency
Office of Water (4303T)
EPA-821-R-02-016
Washington, DC 20460

August 2002

Development Document for Proposed Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Industry Point Source Category

Christine T. Whitman
Administrator

G. Tracy Mehan, III
Assistant Administrator, Office of Water

Geoffrey H. Grubbs
Director, Office of Science and Technology

Sheila E. Frace
Director, Engineering and Analysis Division

Marvin Rubin
Chief, Environmental Engineering Branch

Jan Goodwin
Technical Coordinator

Marta Jordan
Project Manager

Engineering and Analysis Division
Office of Science and Technology
U.S. Environmental Protection Agency
Washington, DC 20460

August 2002

Acknowledgments and Disclaimer

This report has been reviewed and approved for publication by the Engineering and Analysis Division, Office of Science and Technology. This report was prepared with the support of Tetra Tech, Inc., Eastern Research Group, Inc., Science Applications International Corporation (SAIC), Westat, Inc., and DynCorp I&ET, under the direction and review of the Office of Science and Technology.

CONTENTS

FIGURES

TABLES

CHAPTER 1
LEGAL AUTHORITY AND BACKGROUND

This section presents background information supporting the development of effluent limitations guidelines and standards for the concentrated aquatic animal production (CAAP) point source category. Section 1.1 presents the legal authority to regulate the CAAP industry. Section 1.2 discusses the Clean Water Act; Section 1.3 discusses the Clean Water Act Section 304(m) consent decree; and Section 1.4 discusses the Regulatory Flexibility Act (as amended by the Small Business Regulatory Enforcement Fairness Act of 1996). Section 1.5 discusses regional, state, and municipal regulation of the industry. Section 1.6 discusses the regulatory history of the CAAP industry.

1.1 LEGAL AUTHORITY

EPA proposes these regulations under the authority of Sections 301, 304, 306, 307, 308, 402, and 501 of the Clean Water Act (CWA), 33 U.S.C. 1311, 1314, 1316, 1317, 1318, 1342, and 1361.

1.2 CLEAN WATER ACT

Congress adopted the CWA to “restore and maintain the chemical, physical, and biological integrity of the Nation's waters,” (Section 101(a), 33 U.S.C. 1251(a)). To achieve this goal, the CWA prohibits the discharge of pollutants into navigable waters except in compliance with the statute. The CWA establishes restrictions on the types and amounts of pollutants discharged from various industrial, commercial, and municipal sources of wastewater.

Direct dischargers must comply with effluent limitations in National Pollutant Discharge Elimination System (NPDES) permits; indirect dischargers must comply with pretreatment standards. Effluent limitations in NPDES permits are derived on a case-by-case basis using the technology-based standards of the CWA, or are defined from effluent limitations guidelines and new source performance standards promulgated by EPA, as well as from water quality standards. The effluent limitations guidelines and standards are established by regulation for categories of industrial dischargers and are based on the degree of control that can be achieved using various levels of pollution control technology.

Congress recognized that regulating only sources that discharge effluent directly into the Nation's waters would not be sufficient to achieve the goals of the CWA. Consequently, the CWA requires EPA to promulgate nationally applicable pretreatment standards that restrict pollutant discharges from facilities that discharge wastewater indirectly through sewers flowing to publicly owned treatment works (POTWs), (Section 307(b) and (c), 33 U.S.C. 1317(b) and (c)). National pretreatment standards are established for those pollutants in wastewater from indirect dischargers that might pass through, interfere with, or are otherwise incompatible with POTW operations. Generally, pretreatment standards are designed to ensure that wastewaters from direct and indirect industrial dischargers are subject to similar levels of treatment. In addition, POTWs are required to implement local treatment limits applicable to their industrial indirect dischargers to satisfy any local requirements, (40 CFR 403.5).

1.2.1 Best Practicable Control Technology Currently Available (BPT)—Section 304(b)(1) of the CWA

EPA may promulgate BPT effluent limits for conventional, toxic, and non-conventional pollutants. Section 304(a)(4) designates the following pollutants as conventional pollutants: 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), fecal coliform bacteria, pH, and any additional pollutants so defined by the Administrator. The Administrator designated oil and grease as a conventional pollutant on July 30, 1979, (44 FR 44501). The term "toxic pollutant" means those pollutants or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the Administrator, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations, in such organisms or their offspring, (Clean Water Act, Section 502). The USEPA currently lists a total of 128 toxic pollutants or "priority pollutants" in 40 CFR Part 122, Appendix D. A non-conventional pollutant is anything not included in the other two categories.

In specifying limits based on BPT, EPA looks at a number of factors. EPA first considers the cost of achieving effluent reductions in relation to the effluent reduction benefits. The Agency also considers the age of the equipment and facilities, the processes employed, engineering aspects of the control technologies, any required process changes, non-water quality environmental impacts (including energy requirements), and such other factors as the Administrator deems appropriate, (CWA 304(b)(1)(B)). Traditionally, EPA has established BPT effluent limitations based on the average of the best performances of facilities in the industry, grouped to reflect various ages, sizes, processes, or other common characteristics. Where existing performance is uniformly inadequate, however, EPA may establish limitations based on higher levels of control than those currently in place in an industrial category if the Agency determines that the technology is available in another category or subcategory and can be practically applied.

1.2.2 Best Control Technology for Conventional Pollutants (BCT)—Sec. 304(b)(4) of the CWA

The CWA requires EPA to identify additional levels of effluent reduction for conventional pollutants associated with BCT technology for discharges from existing industrial point sources. In addition to other factors specified in Section 304(b)(4)(B), the CWA requires that EPA establish BCT limitations after considering a two-part "cost-reasonableness" test. EPA explained its methodology for the development of BCT limitations in July 1986, (51 FR 24974). The first step in determining limits representing applications of BCT is to establish that a BCT option is technologically feasible (defined as providing conventional pollutant control beyond the level of control provided by the application of BPT). If a BCT option is found to be technologically feasible, the Agency applies a two-part BCT cost test to evaluate the "cost-reasonableness" of the BCT option. The BCT cost test consists of a POTW test and an industry cost-effectiveness test. EPA conducts the POTW test by first calculating the cost per pound of conventional pollutant removed by industrial dischargers in upgrading from BPT to a BCT candidate technology. EPA then compares this cost to the POTW benchmark, which is the cost per pound ($0.65 per pound in 2000 dollars) for a POTW to upgrade from secondary to advanced secondary treatment. EPA calculates the industry cost effectiveness test by comparing the ratio of the cost per pound to go from BPT to BCT divided by the cost per pound to go from raw wastewater to BPT for the industry to 1.29, which is a 29% increase. The results of these tests, along with other industry-specific factors, are evaluated to determine BCT.

1.2.3 Best Available Technology Economically Achievable (BAT)—Section 304(b)(2)(B) of the CWA

In general, BAT effluent limitations guidelines represent the best economically achievable performance of facilities in the industrial category or subcategory. The CWA establishes BAT as a principal national means of controlling the direct discharge of toxic and non-conventional pollutants. The factors considered in assessing BAT include the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the process employed, potential process changes, and non-water quality environmental impacts (including energy requirements) and such other factors as the Administrator deems appropriate. The Agency retains considerable discretion in assigning the weight to be accorded these factors. An additional statutory factor considered in setting BAT is economic achievability. Generally, EPA determines economic achievability on the basis of total costs to the industry and the effect of compliance with BAT limitations on overall industry and subcategory financial conditions. As with BPT, where existing performance is uniformly inadequate, BAT may reflect a higher level of performance than is currently being achieved based on technology transferred from a different subcategory or category. BAT may be based on process changes or internal controls, even when these technologies are not common industry practice.

1.2.4 New Source Performance Standards (NSPS)—Section 306 of the CWA

New Source Performance Standards reflect effluent reductions that are achievable based on the best available demonstrated control technology. New facilities have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the most stringent controls attainable through the application of the best available demonstrated control technology for all pollutants (that is, conventional, non-conventional, and priority pollutants). In establishing NSPS, EPA is directed to take into consideration the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements and to consider a "no discharge" option.

1.2.5 Pretreatment Standards for Existing Sources (PSES)—Section 307(b) of the CWA

Pretreatment Standards for Existing Sources are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of a POTW. Categorical pretreatment standards are technology-based and are analogous to BAT effluent limitations guidelines.

The General Pretreatment Regulations, which set forth the framework for the implementation of categorical pretreatment standards, are at 40 CFR Part 403. These regulations establish pretreatment standards that apply to all nondomestic dischargers, (52 FR 1586 (Jan. 14, 1987)).

1.2.6 Pretreatment Standards for New Sources (PSNS)—Section 307(c) of the CWA

Section 307(c) of the Act requires EPA to promulgate pretreatment standards for new sources at the same time it promulgates NSPS. Such pretreatment standards must prevent the discharge into a POTW of any pollutant that might interfere with, pass through, or otherwise be incompatible with the POTW. EPA promulgates categorical pretreatment standards for existing sources based principally on BAT for existing sources. EPA promulgates pretreatment standards for new sources based on best available demonstrated technology for new sources. New indirect dischargers have the opportunity to incorporate into their facilities the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS that it considers in promulgating NSPS.

1.3 Section 304 and Consent Decree

Section 304(m) requires EPA to publish a plan every 2 years that consists of three elements. First, under section 304(m)(1)(A), EPA is required to establish a schedule for the annual review and revision of existing effluent guidelines in accordance with Section 304(b). Section 304(b) applies to effluent limitations guidelines for direct dischargers and requires EPA to revise such regulations as appropriate. Second, under Section 304(m)(1)(B), EPA must identify categories of sources discharging toxic or non-conventional pollutants for which EPA has not published BAT effluent limitations guidelines under 304(b)(2) or NSPS under Section 306. Finally, under 304(m)(1)(C), EPA must establish a schedule for the promulgation of BAT and NSPS for the categories identified under subparagraph (B) not later than 3 yr after being identified in the 304(m) plan. Section 304(m) does not apply to pretreatment standards for indirect dischargers, which EPA promulgates pursuant to Sections 307(b) and 307(c) of the CWA.

On October 30, 1989, Natural Resources Defense Council, Inc., and Public Citizen, Inc., filed an action against EPA in which they alleged, among other things, that EPA had failed to comply with CWA Section 304(m). Plaintiffs and EPA agreed to a settlement of that action in a Consent Decree entered on January 31, 1992. The Consent Decree, which has been modified several times, established a schedule by which EPA is to propose and take final action for four point source categories identified by name in the Consent Decree and for eight other point source categories identified only as new or revised rules, numbered 5 through 12. EPA selected the aquatic animal production (AAP) industry as the subject for New or Revised Rule 12. Under the Decree as modified, the Administrator was required to sign a proposed rule for the aquatic animal production industry by no later than August 14, 2002, and to take final action on that proposal by no later than June 30, 2004.

1.4 REGULATORY FLEXIBILITY ACT (RFA) AS AMENDED BY THE SMALL BUSINESS REGULATORY ENFORCEMENT FAIRNESS ACT OF 1996 (SBREFA)

The RFA generally requires an agency to prepare a regulatory flexibility analysis for any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute, unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For the purpose of assessing the impact of the CAAP effluent limitations guidelines rule on small entities, a *small entity* is defined as (1) a small business based on full time equivalents (FTEs) or annual revenues established by the Small Business Administration (SBA); (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000 people; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field. The definitions of *small business* for the AAP industry are provided in SBA's regulations under 13 CFR 121.201. These size standards were updated effective February 22, 2002. SBA size standards for the AAP industry, for NAICS codes 112511, 112512, and 112519, define a small business as one with a total amount of revenue of less than $750,000. For the aquarium sector of the AAP industry with NAICS code 712130, a "small business" is defined as one with a total amount of revenue of less than $6 million.

Based on the special tabulation from the 1998 Census of Aquaculture (USDA, 2000) revenue categories (less than $24,999; $25,000 to $49,000; $50,000 to $99,999; $100,000 to $499,999; $500,000 to $999,999; and more than $1 million), EPA identified approximately 4,200 small commercial aquatic animal producers, which represents more than 90% of the total AAP producers. Based on AAP Screener Survey data (Westat, 2002), EPA identified a total of 999 small entities (including 26 small Alaska flow-through facilities that are nonprofits); a total of 344 small entities that met the definition of a CAAP facility; and 48 small entities that are within the scope of the proposed rule (31 flow-through, 12 Alaska, and 5 recirculating). That is, about 95% of the total small entities or 86% of the small CAAP facilities identified in the screener data would not be within the proposed scope. Of the 36 regulated small CAAP facilities that are commercially owned, approximately 17 (which represents 5% of the total small CAAP facilities or 47% of the regulated CAAP facilities) incur compliance costs greater than 1% of aquaculture revenue and 10 small commercial entities (which represent less than 3% of the total small CAAP facilities or 28% of the regulated CAAP facilities) incur compliance costs greater than 3%.

For commercial facilities, EPA assumed that the facility is equivalent to the business, an assumption that will be reexamined when detailed survey data are available. However, because sufficient data are available to determine the parent nonprofit association (and its revenues) for the small Alaska nonprofit facilities, EPA analyzed small entity impacts at the level of the parent association. EPA determined that 12 small Alaska nonprofit facilities within the scope of the proposed rule are owned by 8 small nonprofit associations. Of the six small Alaska nonprofit associations for which EPA had data, three associations incur compliance costs greater than 1% of revenues, and one association incurs compliance costs greater than 3%.

EPA intends to make its final determination of the impact of the CAAP rulemaking on small businesses based on analyses of the data after proposal.

1.5 State, Regional, and Municipal Aquatic Animal Production Regulations

The Aquaculture Act of 1980 required that a list of regulations and permits affecting the aquaculture industry be compiled. In 1993 the United States Department of Agriculture, Cooperative States Research Service (through the Northeastern Regional Aquaculture Center) contracted with the Maryland Department of Agriculture (MDA) to accomplish this task. The organized network of state aquaculture contacts, the National Association of State Aquaculture Coordinators, was contacted for information regarding aquaculture regulations in their states. The resulting information was compiled into a report, *State/Territory Permits and Regulations Impacting the Aquaculture Industry* (Tetra Tech, 2001), which provides an overview of permits and regulations that affect the aquaculture industry, by individual state or territory, during the time at which the report was prepared. This report is available at *www.aquanic.org/publicat/state/md/perm1.htm* (MDA, 1995).

EPA evaluated *State/Territory Permits and Regulations Impacting the Aquaculture Industry* to analyze existing federal, state, and local effluent regulations related to the CAAP industry. As a part of this evaluation for CAAP facilities, EPA updated the report with readily available information, obtained primarily through Internet research. EPA further delineated the state regulations as those directly related to effluents and discharges (e.g., state NPDES permits); those related to water quality, but indirectly related to discharges (e.g., control of nonnative species or pathogens); and those not related to effluents or discharges (e.g., leasing or licensing).

1.5.1 State Regulations

EPA updated *State/Territory Permits and Regulations Impacting the Aquaculture Industry* with information available on-line and through communications with industry representatives (Tetra Tech, 2001). The updated information was compiled in several tables and submitted as a separate memorandum (Tetra Tech, 2001).

1.5.1.1 Regulations Dealing Directly with Effluents and Discharges

EPA found permits and regulations that deal directly with effluents and discharges from CAAP facilities, including NPDES permits; permits and regulations for discharges other than NPDES (injection well, indirect discharge, POTW, sewer, etc.); pesticide regulations; waste handling regulations (sludge application, waste hauling, etc.); and a variety of miscellaneous types of regulations.

National Pollutant Discharge Elimination System Permits

EPA, through its NPDES Program, has set the stage for action by state environmental agencies to regulate effluent discharges from CAAP facilities. A *concentrated aquatic animal production facility* is a hatchery, fish farm, or other facility that contains, grows, or holds aquatic animals in either of the following categories, or that the Director designates as such on a case-by-case basis, and must apply for an NPDES permit:

A. Coldwater fish species or other coldwater aquatic animals including, but not limited to, the Salmonidae family of fish (e.g., trout and salmon) in ponds, raceways, or other similar structures that discharge at least 30 days per year but does not include:

    1. Facilities that produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year; and

    2. Facilities that feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding.

B. Warmwater fish species or other warmwater aquatic animals including, but not limited to, the Ameiuridae, Cetrachidae, and the Cyprinidae families of fish (e.g., respectively, catfish, sunfish, and minnows) in ponds, raceways, or similar structures that discharge at least 30 days per year, but does not include:

    1. Closed ponds that discharge only during periods of excess runoff; or

    2. Facilities that produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) of aquatic animals per year.

EPA has authorized certain States to issue NPDES permits subject to minimum federal requirements. States that have not received authorization to administer the NPDES program are Alaska, Arizona, Idaho, Massachusetts, New Hampshire, and New Mexico; the remaining 44 States, as well as the U.S. Virgin Islands, have authorization to implement the NPDES program.

Discharges

Eleven States and Territories were found to have regulations pertaining to discharges other than NPDES. These are Arkansas, Arizona, California, Guam, Hawaii, Iowa, Massachusetts, New Jersey, Oklahoma, Texas, and Washington. Regulations addressing discharges include city water and sewer municipal permits, industrial wastewater facility permits, waste discharge requirements, and permits for discharging water into injection wells, groundwater, rivers, lakes, or creeks.

Both Arizona and Massachusetts require facilities to obtain a permit before discharging waters into the ground. Several States and Territories, including Guam, Hawaii, Iowa, and Texas, require permits to discharge water into an injection well. In Washington any discharger of pollutants causing below-standard water quality must apply for a modification of the state's water quality standards.

Pesticides

A number of States and Territories were found to have regulations and permits regarding pesticide use in aquaculture, including Alabama, Arkansas, Connecticut, Delaware, Florida, Guam, Iowa, Kansas, Maryland, Michigan, Minnesota, Pennsylvania, South Carolina, Texas, and West Virginia. These regulations address pesticide and include the following issues: use and application; restrictions; record-keeping; waste collection; storage; labeling requirements; and certification, licensing, and registration.

Waste Handling

Four States have regulations that address waste handling of solids generated from aquaculture facilities: Iowa, Illinois, Maryland, and Minnesota. Waste handling regulations in these States address land application of sludge, disposal of sewage and solid waste, and waste hauling permits.

Iowa, Illinois, and Minnesota all have regulations that specifically address land application of sludge. These regulations require individuals to obtain a permit before applying sludge to land. Standards for application vary by state. Maryland's water supply, sewage disposal, and solid waste permit also addresses sewage sludge, including the collection, handling, burning, storage, treatment, land application, and disposal or transportation of solid waste. Sewage sludge is defined as raw sewage sludge, treated sewage sludge, septage, or any product containing these materials that is either generated or utilized in the state.

Illinois has design and maintenance criteria for runoff field application systems. These criteria, which are not classified as a permit, must be met for any party planning to discharge wastewater into a runoff field application, commonly called a vegetative filter system in Illinois. A special waste hauling permit is also required in Illinois for those individuals hauling processing wastes from aquaculture facilities or processing plants for disposal in landfills.

Miscellaneous Permits and Regulations

The following four States have miscellaneous permits or regulations that are related to effluents and discharges of the CAAP industry:

- Arizona has a regulation that addresses best management practices (BMPs) for animal feeding operations, which include CAAP facilities. The regulation specifically covers aquaculture facilities classified as feeding operations for the purposes of regulating discharge water quality. Arizona defines BMPs as practices that can be used to protect the quality of water discharged from aquaculture facilities.
- Georgia has a regulation specifying agricultural BMPs for protecting water quality. Although agriculture is exempted from the Georgia Erosion and Sedimentation Act, this regulation requires agricultural enterprises, such as fish farms, to conduct activities consistent with BMPs established by the Department of Agriculture. In Georgia, BMPs are management strategies for the control and abatement of nonpoint source pollution resulting from agriculture. If waters of the State are impaired by agricultural activities and there appears to be no immediate solution or mitigation, the Environmental Protection Division resolves the problem as a water quality violation.
- Massachusetts requires a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF) for any activity in any saltwater area, or

any other area deemed significant (designated anti-degradation areas exist). Submission of the ENF is the first step in the environmental review of a project under the MEPA. The ENF requires the project proponent to answer specific questions regarding the likely environmental impacts of the proposed project. The ENF is submitted to the MEPA Office of the Massachusetts Executive Office of Environmental Affairs (EOEA), which determines if the likely impacts require the submission of an Environmental Impact Report (EIR). The public is encouraged to provide written comments as part of this review process. The findings of the Secretary of EOEA are written in the form of a certificate.

- Montana provides a short-term exemption from the State's surface water quality standards (3A Authorization). This authorization, which must be obtained prior to initiating a project, concerns any activity in any state water that will cause unavoidable violations of water quality standards. Authorization may be obtained from the Water Quality Bureau, or may be waived by the Department of Fish, Wildlife, and Parks during its review process. This authorization extends to aquaculture facilities.

1.5.1.2 Regulations Dealing Indirectly with Effluents and Discharges

EPA found aquaculture regulations indirectly related to effluents and discharge. These types of regulations include construction storm water permits, disease control and protection of fish and wildlife health, nonnative species, water supply, and other types of regulations.

Construction and Storm Water

Eleven States and Territories have regulations or permits that address construction and storm water runoff controls: Alabama, Delaware, Guam, Illinois, Maryland, Michigan, New Jersey, Puerto Rico, South Carolina, Vermont, and Washington. Types of permits and regulations addressed by these States and Territories include construction storm water permits, erosion and sedimentation control permits, clearing and grading permits, excavation permits, storm water management and sediment reduction permits, permits for dam or pond construction or enlargement, approval for hydraulic projects, and regulations regarding extraction of materials from the earth's crust. These types of permits and regulations seek to limit environmental impacts caused by construction and earthmoving activities, such as erosion, increased water turbidity, water temperature effects, and negative impacts on aquatic life. The storm water permits and regulations are intended to help reduce the water quantity and quality impacts associated with sites during and after construction.

Disease Control and Protection of Fish and Wildlife Health

Sixteen States or Territories have regulations or permits related to disease control or protection of fish and wildlife health: Alaska, Alabama, Arkansas, Arizona, Connecticut, Delaware, Michigan, Minnesota, Missouri, Montana, North Dakota, Nevada, South Dakota, Washington, Wisconsin, and West Virginia. Regulations or permits in this category include those that address disease control, fish importation precautions, inspection and certification of facilities and fish, and methods for proper handling, processing, and transporting of fish. Connecticut has a regulation that sets standards for shellfish depositing in tidal waters when the shellfish were imported from outside the state.

Nonnative Species

EPA found 22 States and Territories that have reported having regulations or permits dealing with importation or possession of nonnative species: Alabama, Arizona, California, Colorado, Connecticut, Florida, Guam, Iowa, Illinois, Indiana, Louisiana, Michigan, Minnesota, Mississippi, Nebraska, New Hampshire, Ohio, South Carolina, Tennessee, Texas, Virginia, and Wisconsin. Types of permits and regulations dealing with nonnative species include stocking licenses, general importation permits for aquatic species and plants, and restrictions on possession, sale, importation, transportation, and release of nonnative species. Some states have special importation permits regarding specific species of aquatic animals such as grass carp (or white amur), crawfish, piranha, and rudd.

Water Supply

Regulations and permits related to water supply address water diversion, water allocation and appropriation, water well construction and drilling, water withdrawal and storage, dam construction or alteration, and use of ground, stream, or surface waters. States and Territories with these types of regulations and permits include Alabama, Arizona, California, Colorado, Connecticut, Delaware, Florida, Georgia, Guam, Hawaii, Iowa, Idaho, Illinois, Kansas, Massachusetts, Maryland, Michigan, Minnesota, Montana, Oklahoma, Puerto Rico, South Carolina, Texas, Virginia, Washington, and Wyoming. These regulations are important to the aquaculture industry because water supply is an essential component for aquaculture facilities to be able to operate. Water supply is a major concern in many parts of the United States, especially in arid regions.

Two notable water supply regulations are being used in Florida and Georgia. Florida's environmental resource permit is a comprehensive regulatory program that covers any activity that might alter surface water flows. The permit also involves an evaluation of the effects the activity will have on flooding, storm water, and environmental factors such as water quality, wildlife, and habitats of wetlands and water-dependent species. Georgia's regulation regarding approval to impound or discharge in trout waters does not allow any person to construct an impoundment on primary or secondary trout waters without approval from the Environmental Protection Division. This regulation also restricts temperature elevations that might be caused by impoundments in both primary and secondary trout waters.

Miscellaneous Permits and Regulations

Twelve States and Territories have miscellaneous regulations and permits indirectly related to effluents and discharge: California, Delaware, Florida, Hawaii, Illinois, Maryland, Minnesota, Montana, New York, Puerto Rico, Rhode Island, and Wisconsin. The regulations and permits in this category address several areas that are indirectly related to effluents and discharge, and they include the following:

- California has a streambed alteration agreement that is used to avoid or mitigate any adverse impacts on fish and wildlife resources caused by a project.

- Delaware requires an application for drainage of lands by tax ditches. This application is needed for water management and flood prevention on lands subject to overflow. Owners of land desiring drainage or protection from flooding may petition for the formation of a tax ditch to the Superior Court of the county in which all or a major portion of area to be drained or protected is located.
- Florida requires a general permit for the installation and maintenance of intake and/or discharge pipes associated with marine bivalve facilities.
- In Hawaii, a conservation district use application is required prior to undertaking any proposed use (aquafarming) of lands within the conservation district. The conservation district encompasses large areas of mountain and shoreline lands, areas necessary to protect watersheds, all submerged ocean lands, and most ancient fish ponds. Hawaii also requires zone of mixing approval for aquaculture effluent discharge into certain coastal waters. This application is made concurrently with NPDES.
- Illinois requires a construction permit for anyone constructing a new, or modifying an existing, emission source or installing any new air pollution control equipment. Anyone operating an existing emission source or air pollution control equipment must first obtain an operating permit.
- In Maryland, approval is required for all state and local agency-sponsored activities or programs affecting the critical area (1,000 feet from the mean high water line of tidal waters or the landward side of tidal wetlands).
- Minnesota requires a permit for all aeration systems installed and operated in protected waters. A private fish farm or hatchery license may contain authorization for the operation of aeration systems on protected waters without public access if the licensee owns all riparian land or all of the possessory rights to the riparian lands. A private hatchery or fish farm license application requesting authorization for an aeration system operation is subject to the same review as the aeration permit application.
- In Montana, the Flood Plain and Floodway Management Act addresses new construction in floodplains. Montana also has a stream protection permit that addresses any project, including the construction of new facilities or the modification, operation, and maintenance of an existing facility, that might affect the natural existing shape and form of any stream or its banks and tributaries. Montana’s streambed and land preservation permit addresses any activity that physically alters or modifies the bed and banks of a stream.
- New York’s State Environmental Quality Review (SEQR) Act does not require permits, but rather establishes a process to help the government and the public protect and improve the environment by ensuring that environmental factors are considered along with social and economic considerations in government decision-making. SEQR applies to any state, regional, or local government agency approving, undertaking, or funding a privately or publicly sponsored action. Applicants seeking project approval or funding may be required to prepare an environmental impact statement.

- Puerto Rico also requires environmental impact statements for projects that might adversely affect the environment.
- In Rhode Island, a coastal resources assent or application is required for any alteration or aquaculture use activities in coastal waterways. The application is reviewed for approval, and application fees are required.
- In Wisconsin, barriers are required for the body of water used as a fish farm or part of a fish farm to prevent the passage of fish between the farm and other waters of the state.

1.5.1.3 Regulations Addressing All Other Types of Aquaculture-Related Activities

EPA found other types of aquaculture-related permits and regulations, including animal possession, licensing and permitting of CAAP activities, processing, inspection, depuration, leasing, taxes, and a number of miscellaneous regulations and permits.

Possession

Regulations and permits included in the possession category include stocking, propagating, cultivating, transporting, transferring, harvesting, taking, trapping, collecting, selling, trading, wet storage, and purchasing. Thirty States have regulations and permits involving the possession of animals for aquaculture-related activities: Alaska, Alabama, Arizona, California, Connecticut, Delaware, Florida, Georgia, Iowa, Idaho, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Montana, Nebraska, New Hampshire, New Jersey, Nevada, New York, Ohio, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Virginia, Vermont, and Wisconsin.

Licensing and Permitting

Forty States and Territories have several licensing and permitting regulations or permits associated with aquaculture: Alaska, Alabama, Arkansas, Arizona, California, Colorado, Connecticut, Florida, Georgia, Guam, Iowa, Idaho, Illinois, Indiana, Louisiana, Massachusetts, Maryland, Michigan, Minnesota, Mississippi, North Carolina, North Dakota, Nebraska, New Hampshire, Nevada, New York, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Virginia, Vermont, Washington, Wisconsin, West Virginia, and Wyoming. Regulations and permits included in this category address the actual licensing and permitting of facilities for conducting aquaculture activities. This category also contains fish and bait dealer licenses, general permits, marketing permits, permits that cover all aquaculture-related activities, and permits, certificates, or licenses for fee-fishing, boat use, registration of aquaculture operations, and education and research institutional needs.

Processing

Fifteen States have aquaculture-related processing regulations: Arkansas, Arizona, California, Connecticut, Florida, Georgia, Michigan, Minnesota, New Jersey, New York, Oklahoma, Pennsylvania, South Carolina, Texas, and West Virginia. Regulations or permits included in the processing category specifically address requirements for processing of aquatic animals and products, including licenses for purchasing, packing, repacking, shipping, reshipping, shucking, culling, and selling.

Inspection

Arizona requires inspection and certification of aquaculture facilities. Facilities are periodically inspected to ensure compliance with all laws related to aquaculture and to ensure that facilities are disease-free.

Depuration

Two States have regulations or permits that specifically address depuration, which is the purging of contaminants from shellfish. In Connecticut a shellfish depuration license is required for the operation of a depuration plant and the sale of processed shellfish. Florida requires a special activity license for depuration of oysters and clams in controlled purification facilities.

Leasing

Thirteen States have regulations or permits regarding leasing of submerged public land: Alaska, California, Connecticut, Delaware, Florida, Louisiana, Maine, North Carolina, New Jersey, Rhode Island, Texas, Virginia, and Washington. Most of the leasing regulations or permits address leasing of state or publicly owned tidal or subtidal ocean water bottoms for shellfish or oyster operations. In North Carolina, a lease is required for the use of an entire water column for the private production of shellfish.

Taxes

Three States have regulations or permits addressing aquaculture-related taxes. Alabama and Arkansas both require a city privilege tax for businesses inside city limits. Some cities even have specific permits for fish markets, which would otherwise be covered by a general permit. Arkansas also requires a sales and use tax permit. Any business that provides a service or merchandise must pay a deposit of $250 to receive a sales and use tax permit. A refund is granted within 6 months if that business or its sales outlets do not charge sales tax to its customers. Also included in the taxes category are Pennsylvania's sales tax and capital stock franchise tax regulations.

Miscellaneous Permits and Regulations

Twenty-four States and Territories have miscellaneous regulations and permits that are related to other CAAP activities: Alabama, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Illinois, Indiana, Michigan, Mississippi, New York, Oregon, Puerto Rico, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Virginia, Washington, Wisconsin, West Virginia, and Wyoming. Regulations and permits in this category address a variety of subjects and include the following:

- In Alabama, regulations cover procedures and guidelines for dealing with nuisance alligators.
- Arkansas requires a feed license for anyone who manufactures or distributes commercial feed or has their name appear on the label as a commercial feed guarantor.
- California's shellfish safety regulations cover requirements for the safe handling of shellfish. California also requires a weighmaster license for weighing, measuring, or counting any commodity and for issuing a statement used as the basis for either the purchase or the sale of that commodity or charge for service.

- Colorado requires a private easement for erecting intake/discharge structures and for dredging and filling on state-owned submerged lands.
- In Connecticut, shellfish safety regulations provide requirements for the safe handling of shellfish. Connecticut also requires shellfish transplant licenses for both the short and long term. These transplant licenses are required to relay oysters from prohibited areas into private shellfish beds in approved areas.
- Delaware requires a subaqueous lands permit, which does not allow a person to deposit material upon, extract material from, construct, modify, repair, reconstruct, or occupy any structure or facility on submerged lands or tidelands without first obtaining a permit.
- Florida requires a special activity license for any person to use gear or equipment not authorized by the Fish and Wildlife Conservation Commission for harvesting saltwater species. Florida also requires a private easement for erecting any intake or discharge structures and for dredging and filling on state-owned submerged lands.
- Illinois requires a license for disposing of dead animals and a permit for removing undesirable fish from state waters.
- In Indiana, all manufacturers and wholesale distributors of food (excluding meat, poultry, and dairy products) must apply for a registration of business.
- In Michigan, regulations cover proper procedures for dealing with the bodies of dead animals, including composting of dead fish from aquaculture activities.
- Mississippi requires that all tilapia products offered for direct sale for human consumption have the product name specifically labeled in the manner described by the state's regulations.
- In New York, regulations control any new or expanded land use and development that is defined as a Class A or B regional project. New York also requires fish tags for identifying hatchery-raised fish and permits to install a fish screen and to remove or transfer fish.
- Oregon has numerous overlapping permits and state government regulatory permits for the kinds of aquaculture permitted in the state. To begin the permitting process, an applicant should first contact the Oregon Department of Fish and Wildlife.
- Puerto Rico was vague in describing its specific aquaculture regulations, indicating that it has zoning and building regulations pertaining to aquaculture.
- Rhode Island may require the execution of a bond by the permittee to ensure the permittee's performance of all conditions of the permit and, in the event of failure to perform, to ensure the removal of aquaculture apparatus from the waters of the state.
- In South Carolina, harvesting equipment permits are required to use dredges, hydraulic escalators, patent tongs, or any other mechanically operated device for taking shellfish from any bottom. South Carolina also requires a license for using

powerboats or other vessels equipped with commercial fishing equipment for taking shellfish.

- South Dakota's regulation on contract commercial fishing for rough and bullheads covers the bond required and activities such as supervision, equipment tagging, sale and transportation of fish, and deposition of game fish taken.
- In Tennessee, an animal damage permit is required for any person, company, or other entity desiring to destroy, or otherwise control, nuisance wildlife and charge a fee for such services.
- Texas requires shell dredging permits for all shell dredging in state-owned submerged tidelands. In Texas, aquaculture producers may be subject to other permits, licenses, or approvals.
- Virginia's food quality sanitation regulations govern the inspection of food manufacturers, warehouses and retail food stores, food product sampling, and food product label review.
- In Washington, regulations cover the identification requirements for products cultivated by aquatic farmers. Washington also has shellfish certification regulations, which cover shellfish sanitation and practices, including certificate of compliance, certificates of approval for shellfish growing areas, and certificates for culling, shucking, and packing facilities.
- Wisconsin's permit for private management allows a person who owns all of the land bordering a navigable lake that is completely landlocked to remove, destroy, or introduce fish. Wisconsin also has a permit that allows a person to use a natural body of water for a fish farm.
- All places in West Virginia that tender to the public any item for human consumption need a permit for water well installations and on-site sewage system installations.
- In Wyoming, food safety regulations cover good manufacturing practice labeling. Wyoming also requires a mining permit for removal of solid minerals from the earth for commercial purposes including some forms of aquatic animal production.

1.5.2 Federal Regulations

EPA evaluated other federal statutes and regulations that might affect the CAAP industry (Tetra Tech, 2001). The following federal statutes and regulations address a variety of areas that might apply to CAAP facilities:

- *Section 404 of the Federal Water Pollution Control Act of 1972 as amended by the Clean Water Act of 1977 and the Water Quality Act of 1987*: Section 404 deals with permits for dredged and filled sites. More specifically, Section 404 establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Activities in waters of the United States that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry.

- *Federal Coastal Zone Management Act of 1972, as amended*: The Coastal Zone Management Act (CZMA) deals with proposed federal activities affecting a state's coastal zone. Activities include direct federal agency actions, federal licenses and permits, and financial assistance to state and local governments. The requirements of CZMA apply to all States in the "coastal zone," including parts of the Great Lakes.
- *Section 10 of the Rivers and Harbors Act (RHA) of 1899*: Section 10 states that the creation of any obstruction not affirmatively authorized by Congress to the navigable capacity of any of the waters of the United States is prohibited.
- *Federal Standard Sanitation Standards for Fish Plants*: This regulation describes an optional Quality Assurance Inspection in which U.S. Department of Commerce inspectors will, upon request, inspect processing plants and facilities, and grade aquaculture products for quality assurance (50 CFR Part 260).
- *Endangered Species Act of 1973*: This statute deals with any activity that might affect endangered or threatened species or their habitat.
- *Lacey Act Amendments of 1981*: Under this law, it is unlawful to import, export, sell, acquire, or purchase fish, wildlife, or plants taken, possessed, transported, or sold (1) in violation of U.S. or Indian law or (2) in interstate or foreign commerce involving any fish, wildlife, or plants taken, possessed, or sold in violation of state or foreign law.
- *Migratory Bird Treaty Act*: The Migratory Bird Treaty Act regulates the use of lethal control methods on migratory birds, which are causing aquaculture crop losses. USFWS issues permits for the control of these migratory birds.
- *Wild and Scenic Rivers Act*: Permits issued under the wild, scenic, and recreational rivers systems program are intended to control land use and development along river corridors specifically designated under the system and to protect and preserve the river qualities that qualified the particular rivers designated under the system. This program is jointly managed by the USFWS and any other agency that might hold title to involved lands.
- *Section 106 of the National Historic Preservation Act of 1966, as amended through 1992*: The head of any federal agency having direct or indirect jurisdiction over a proposed federal or federally assisted undertaking in any state and the head of any federal department or independent agency having authority to license any undertaking must, prior to the approval of the expenditure of any federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register.

1.6 Regulatory History of the Concentrated Aquatic Animal Production Industry

Until the current proposed regulation, EPA had not proposed effluent limitations guidelines and standards for the concentrated aquatic animal production industry. In the early 1970s, however, EPA staff did evaluate fish hatcheries and fish farms to develop recommendations on whether the Agency should propose effluent guidelines in conjunction with this evaluation. Ultimately, EPA did not propose any such regulations because the 1977 Clean Water Act amendments had refocused the Agency's attention on establishing effluent limitations guidelines for industry sectors with effluents containing toxic metals and organics. EPA's evaluation of fish hatcheries and farms did not reveal significant contributions of toxic metals or organic chemical compounds in the wastes discharged from those facilities. That draft development document, however, did assist NPDES permit writers in the exercise of their "best professional judgment" to develop permits for those fish hatcheries and farms that were considered "concentrated aquatic animal production facilities" and thus were required to apply for NPDES permits under EPA regulations.

EPA actions to regulate concentrated aquatic animal production facilities under the NPDES permitting program date back to 1973, when the Agency proposed and promulgated NPDES permit application rules for CAAP facilities, (38 FR 10960 (May 3, 1973); (proposed), 38 FR 18000 (July 5, 1973)). After some litigation over the NPDES regulations, EPA proposed and took final action to reestablish the CAAP facility requirements, (*NRDC* v. *Costle*, 568 F.2d 1369 (D.C. Cir. 1977); 43 FR 37078 (Aug. 21, 1978); 44 FR 32854 (June 7, 1979)). To date, the 1979 version of the regulations has not substantively changed since then.

The NPDES regulations specify the applicability of the NPDES permit requirement to a concentrated aquatic animal production facility, the definition of which can be found at 40 CFR 122.24 and Appendix C to Part 122. To be a CAAP facility, the facility must either meet the criteria in 40 CFR Appendix C or be designated on a case-by-case basis (40 CFR 122.24(b)). A hatchery, fish farm, or other facility is a CAAP facility if it contains, grows, or holds aquatic animals in either of two categories: coldwater species or warmwater species. The coldwater species CAAP facilities must discharge at least 30 d/yr; however, facilities that produce less than 9,090 harvest weight kg (approximately 20,000 lb) per year and facilities that feed less than 2,272 kg (approximately 5,000 lb) during the calendar month of maximum feeding are not defined as CAAP facilities. The warmwater CAAP facilities must discharge at least 30 d/yr, but closed ponds that discharge only during periods of excess runoff or facilities that produce less than 45,454 harvest weight kg (approximately 100,000 lb) per year are not defined as CAAP facilities (40 CFR 122 Appendix C).

1.7 References

MDA (Maryland Department of Agriculture). 1995. *State/Territory Permits and Regulations Impacting the Aquaculture Industry*. Maryland Department of Agriculture. <http://www.aquanic.org/publicat/state/md/perm.htm>. Accessed September 2001.

Tetra Tech, Inc. 2001. Technical Memorandum: Updates to the Report State/Territory Permits and Regulations Impacting the Aquaculture Industry. Tetra Tech, Inc., Fairfax, VA.

USDA (U. S. Department of Agriculture). 2000. *The 1998 Census of Aquaculture.* U.S. Department of Agriculture, National Agriculture Statistics Service, Washington, DC.

Westat. 2002. *AAP Screener Survey Production Range Report, Revision IV*. Westat, Inc., Rockville, MD.

CHAPTER 2
SUMMARY OF SCOPE AND PROPOSED REGULATION

This chapter presents a summary of the proposed rule for the concentrated aquatic animal production (CAAP) industry. The proposed rule includes effluent limitations guidelines (ELGs) based on treatment technologies or best management practices (BMPs) for the control of pollutants. Section 2.2 summarizes and discusses the applicability of the National Pollutant Discharge Elimination System (NPDES) regulations, and Section 2.3 summarizes and discusses the applicability of the proposed effluent limitations guidelines and standards for the CAAP industry.

2.1 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

The NPDES regulations specify the applicability of the NPDES permit requirement to a concentrated aquatic animal production facility in 40 CFR 122.24 and Appendix C to Part 122. To be a concentrated aquatic animal production facility, the facility must either meet the criteria in 40 CFR Part 122 Appendix C or be designated on a case-by-case basis (40 CFR 122.24(b)). A hatchery, fish farm, or other facility is a concentrated aquatic animal production facility if it contains, grows, or holds, aquatic animals in either of two categories (40 CFR Appendix C to Part 122):

> The **coldwater** species category includes ponds, raceways, or other similar structures which discharge at least 30 days per year but does not include: facilities which produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) per year; and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) during the calendar month of maximum feeding. *Coldwater aquatic animals* include, but are not limited to, the Salmonidae family of fish; e.g., trout and salmon.
>
> The **warmwater** category includes ponds, raceways, or other similar structures which discharge at least 30 days per year but does not include: closed ponds which discharge only during periods of excess runoff; or facilities which produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) per year. *Warmwater aquatic animals* include, but are not limited to, the Ameiuride, Centrarchidae, and Cyprinidae families of fish; e.g., respectively catfish, sunfish, and minnows.

EPA does not propose to revise the NPDES regulation.

2.2 EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS

The proposed effluent limitations guidelines and standards regulations would establish the Best Practicable Control Technology Currently Available (BPT), Best Control Technology for Conventional Pollutants (BCT), and Best Available Technology Economically Achievable (BAT) limitations, as well as New Source Performance Standards (NSPS). EPA does not propose any pretreatment standards for this industry. The indirect dischargers would discharge mainly total suspended solids (TSS) and biochemical oxygen demand (BOD), which the publicly owned treatment works (POTWs) are designed to treat. In addition, the nutrients discharged from CAAP facilities that might pass through the POTW are at concentrations similar to nutrient concentrations in human wastes discharged to POTWs. The options EPA considered do not directly treat for nutrients, but nutrients are incidentally removed through the control of TSS. EPA believes that the POTW removals of TSS would achieve nutrient removals equivalent to those obtained by the options considered for this proposed rulemaking and therefore concludes there would be no pass through of pollutant amounts necessitating regulation.

2.2.1 Regulatory Implementation of Part 451 Through the NPDES Permit Program and the National Pretreatment Program

Under Sections 301, 304, 306, and 307, of the Clean Water Act (CWA), EPA promulgates national effluent limitations guidelines and standards of performance for major industrial categories for three classes of pollutants: (1) conventional pollutants (i.e., total suspended solids, oil and grease, biochemical oxygen demand, fecal coliforms, and pH); (2) toxic pollutants (e.g., toxic metals such as chromium, lead, nickel, and zinc; toxic organic pollutants such as benzene, benzo-*a*-pyrene, phenol, and naphthalene); and (3) non-conventional pollutants (e.g., ammonia, formaldehyde, and phosphorus).

EPA considers development of six types of effluent limitations guidelines and standards for each major industrial category, as appropriate:

Abbreviation	Effluent Limitation Guideline or Standard
BPT	Best Practicable Control Technology Currently Available
BAT	Best Available Technology Economically Achievable
BCT	Best Control Technology for Conventional Pollutants
NSPS	New Source Performance Standards
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources

The effluent limitations guidelines and new source performance standards apply to industrial facilities with direct discharges to navigable waters. Pretreatment standards apply to industrial facilities with wastewater discharges to POTWs. As noted above, EPA has not proposed categorized pretreatment standards for the CAAP industrial category.

2.2.1.1 NPDES Permit Program

Section 402 of the CWA establishes the NPDES permit program. The NPDES permit program is designed to limit the discharge of pollutants into navigable waters of the United States through a combination of various requirements, including technology-based and water quality-based effluent limitations. This proposed regulation contains the technology-based effluent limitations guidelines and standards applicable to the concentrated aquatic animal production industry to be used by permit writers to derive NPDES permit technology-based effluent limitations. Water quality-based effluent limitations are based on receiving water characteristics and ambient water quality standards, including designated water uses. They are derived independently from the technology-based effluent limitations set out in this proposed regulation. The CWA requires that NPDES permits must contain, for a given discharge, the more stringent of the applicable technology-based or water quality-based effluent limitations for any given pollutant of concern.

Section 402(a)(1) of the CWA provides that in the absence of promulgated effluent limitations guidelines or standards, the Administrator, or her designee, may establish technology-based effluent limitations for specific dischargers on a case-by-case basis. Federal NPDES permit regulations provide that these limits may be established using "best professional judgment" (BPJ) taking into account any proposed effluent limitations guidelines and standards and other relevant scientific, technical, and economic information, as well as the statutory technology-based standards of control.

Section 301 of the CWA requires that BAT effluent limitations for toxic pollutants are to have been achieved as expeditiously as possible, but not later than 3 years from the date of promulgation of such limitations and in no case later than March 31, 1989. (See § 301(b)(2).) Because the proposed 40 CFR Part 451 regulations would be promulgated after March 31, 1989, NPDES permit effluent limitations based on the effluent limitations guidelines would need to be included in the next NPDES permit issued after promulgation of the regulation, and the permit would need to require compliance effective upon issuance.

2.2.1.2 New Source Performance Standards

New sources would need to comply with the new source performance standards and limitations of the CAAP rule (once it is finalized) at the time such sources commence discharging CAAP process wastewater. Because the final rule is not expected to be promulgated within 120 days of the proposed rule, the Agency would consider a discharger to be a new source if construction of the source begins after promulgation of the final rule. EPA expects to take final action on this proposal in June 2004.

2.2.1.3 Pollutants in Intake Water (Net Limitations)

The TSS limitations being proposed are based on the implementation of production management controls and wastewater treatment. Depending on the quality of the intake water and the specific needs and tolerance of the species being raised, some facilities might or might not currently employ pretreatment of intake waters prior to their use in the production systems. EPA does not intend that the proposed limits would force facilities that otherwise would not pretreat their intake waters to do so. EPA is proposing to apply the TSS limitations on a net basis, such that the TSS content of the intake waters would be subtracted from the TSS content of the effluent in determining compliance with any such final TSS limitation. This credit for intake water pollutant content is consistent with the provisions of 40 CFR 122.45(g) and more closely reflects the ability of controls and treatment to minimize the addition of TSS by the production systems. EPA solicits comment on whether facilities that pretreat intake waters in order to sustain the growth of aquatic organisms should base the net calculations on the content of the intake waters subsequent to that pretreatment, but prior to use in the production system.

2.2.1.4 National Pretreatment Standards

The national pretreatment standards at 40 CFR Part 403 have three principal objectives: (1) to prevent the introduction of pollutants into publicly owned treatment works (POTWs) that will interfere with POTW operations including use or disposal of municipal sludge; (2) to prevent the introduction of pollutants into POTWs which will pass through the treatment works or will otherwise be incompatible with the treatment works; and (3) to improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

The national pretreatment and categorical standards comprise a series of prohibited discharges to prevent the discharge of "any pollutant(s) which cause Pass Through or Interference." (See 40 CFR 403.5(a)(1).) Local control authorities are required to implement the national pretreatment program including application of the federal categorical pretreatment standards to their industrial users that are subject to such categorical pretreatment standards, as well as any pretreatment standards derived locally (i.e., local limits) that are more restrictive than the federal standards. This proposed regulation would not establish federal categorical pretreatment standards (PSES and PSNS) applicable to concentrated aquatic animal production facilities that would be regulated by 40 CFR Part 451.

2.2.2 Applicability of the Proposed Rule

EPA has proposed subcategorization of the CAAP point source category based on production system type. See Chapter 5 for a discussion on subcategorization. The proposed subcategories are listed in Table 2.2-1. The proposal would apply to facilities that annually produce more than 100,000 lb of aquatic animals in three types of production systems: recirculating, flow-through, and net pens. EPA did not propose regulations for pond systems because of the minimal pollutant discharges and because the pond itself acts as an effective treatment system.

EPA established general reporting requirements (§ 451.3) for the use of drugs and chemicals that are investigational new animal drugs and any drugs and chemicals not used according to the label. Flow-through system facilities that produce less than 475,000 lb per year would be exempt from the general reporting requirements for drugs and chemicals.

Table 2.2-1. Applicability of Proposed Rule to CAAP Subcategories

System Type or Subcategory	***Annual Production (lb)***		
	<100,000 (Small)	***100,000 to 475,000 (Medium)***	***>475,000 (Large)***
Pond	Exempt	Exempt	Exempt
Flow-through	Exempt	451.3(a), (b) 451.4 451.11(b), (c) 451.12–14 451.15(b)–(d)	451.3(a), (b) 451.4 451.11(a) 451.12-15
Recirculating	Exempt	451.3(a), (b) 451.4 451.2–	451.3(a), (b) 451.4 451.2–
Net pen	Exempt	451.3– 451.3(a), (b)	451.3– 451.3(a), (b)

The permittee would need to notify the permitting authority of the addition directly to an aquatic animal production facility (subject to this Part) of any investigational new animal drug (i.e., a drug for which there is a valid exemption in effect under 512(j) of the Federal Food, Drug, and Cosmetic Act, 21.U.S.C. 360b(j)) and any drug that is not used according to label requirements, as well as any chemical that is not used according to label requirements. For drugs and chemicals that are not used according to label requirements:

- The permittee would need to provide an oral report to the permitting authority within 7 days after initiating application of the drug or chemical. The oral report would need to identify the drug and/or chemical added and the reason for adding the drug and/or chemical.
- The permittee would need to provide a written report to the permitting authority within 30 days after conclusion of the addition of the drug or chemical. The written report would need to identify the drug and/or chemical added and include: the reason for treatment, date(s) and time(s) of the addition (including duration); the total amount of active ingredient added; the total amount of medicated feed added (only for drugs applied through medicated feed), and the estimated number of aquatic animals medicated by the addition.

For investigational new animal drugs, the permittee would need to provide a written report to the permitting authority within 30 days after conclusion of the addition of any investigational new drug. The written report would need to identify the drug added including: the reason for treatment, date(s) and time(s) of the addition (including duration); the total amount of active ingredient added; the total amount of medicated feed added (only for drugs applied through medicated feed), and the estimated number of aquatic animals medicated by the addition.

EPA also proposed to establish the general requirement of BMP plan certification for all facilities. The certification requires the facility owner or operator to certify that a BMP plan was developed and would meet the objectives of the regulation. The plan would need to be available to the permitting authority if requested.

2.2.3 Summary of the Proposed Effluent Limitations Guidelines and Standards

The proposed guidelines establish BPT, BCT, BAT, and NSPS based on treatment technologies or BMPs evaluated for each of the subcategories. EPA evaluated the following options in the development of the ELGs for the proposed subcategories:

> *Option 1*. Development of a BMP plan for all subcategories and numeric limitations for TSS based on primary settling for flow-through and recirculating systems.
>
> *Option 2*. Option 1 + development of a BMP plan to address the use of drugs and chemicals, escapes of nonnative species, and mortality removal for all subcategories except the medium facilities within the flow-through subcategory.
>
> *Option 3*. Option 2 + numeric limits for flow-though and recirculating systems based on additional solids treatment and active feed monitoring for net pens.

The options are additive in nature, and represent increasing stringency; thus, Option 2 limitations would be based on, and incorporate, primary settling (Option 1) in addition to the limitations based on BMP considerations under Option 2. These options are further discussed in Chapters 9 and 10.

2.2.3.1 BPT

Flow-through Systems

EPA is proposing (1) no nationally applicable effluent limitations guidelines for facilities producing less than 100,000 lb/yr, (2) effluent limitations based on Option 1 for facilities producing 100,000 lb/yr up to 475,000 lb/yr, and (3) effluent limitations based on Option 3 for facilities producing 475,000 lb/yr or more.

For small flow-through facilities (facilities that produce between 20,000 and 100,000 lb/yr of cold water species), the proposed rule would not establish any national requirements for existing flow-through facilities. EPA's analysis estimated that the economic impacts below the 100,000 lb/yr threshold were significant. EPA determined that by considering different levels of control for the two production thresholds established, the unreasonable cost impacts would be minimized.

Any flow-through facilities below the production threshold of 100,000 lb/yr would still be subject to existing NPDES regulations and would be subject to permit limits based on the permit writer's "best professional judgment" if the facility is a "concentrated aquatic animal production facility" under the existing NPDES regulations.

For facilities producing 100,000 lb/yr up to 475,000 lb/yr, the proposed rule would establish BPT limits based on primary settling, including quiescent zones and settling basins and/or BMP development (Option 1) for existing flow-through facilities.

For facilities producing 475,000 lb/yr or more, the proposed rule would establish limits based on solids polishing and/or a requirement to develop and implement a BMP plan

(Option 3). EPA considered the impacts of such proposal requirements on these larger facilities and, based on the results, determined that 475,000 lb/yr would be an appropriate threshold for which the costs of compliance would remain cost reasonable.

EPA is also proposing to establish limits for TSS discharged from separate off-line treatment systems (i.e., physically separate and discharging from an outfall distinct from the main flow of the system) based on Option 3 technology performance. For these systems, EPA also proposes a BMP plan for solids control in the bulk, or main, discharge of the system. A summary of the BPT requirement alternatives for flow-through systems is provided in Table 2.2-2 at the end of this chapter.

Recirculating Systems

EPA is proposing to establish BPT limits on the basis of solids polishing (i.e., additional solids removal) including a settling basin and the development of a BMP plan, and general reporting requirements for drug and chemical use (Option 3) for existing recirculating facilities that produce more than 100,000 lb/yr. This option is technically available for recirculating systems at this size threshold. A summary of the BPT requirement alternatives for recirculating systems is provided in Table 2.2-2 at the end of this chapter.

Net Pen Systems

EPA is proposing to establish BPT limits on the basis of active feed monitoring (i.e., additional solids removal) and the development of a BMP plan, and general reporting requirements for use of certain drugs and chemicals (Option 3) for facilities that produce more than 100,000 lb/yr as the technology basis for the effluent limitations guidelines for existing sources in the proposed rule. A summary of the BPT requirement alternatives for net pen systems is provided in Table 2.2-2 at the end of this chapter.

2.2.3.2 BCT and BAT

Flow-through Systems

EPA proposes to establish BCT and BAT at a level equal to BPT for flow-through systems.

EPA is establishing BPT limitations for flow-through facilities with an annual production of 100,000 lb and greater. A BCT test can be performed for the category with 100,000 up to 475,000 lb in annual production. (EPA is proposing the most stringent option for facilities with 475,000 lb and greater in annual production. Hence, there is no more stringent option to be considered for BCT for this group.) For purposes of this analysis, EPA is assuming that the proposed BPT limits are baseline. Thus, EPA is considering only Options 2 and 3 as BCT candidate options. EPA’s analyses found that Option 3 fails the second part of the cost reasonableness test. Based on these results, EPA is proposing that BCT be set equal to BPT.

Because EPA projects limited economic impacts associated with BPT requirements, EPA does not expect significant economic impacts for BAT. EPA did not select the more stringent Option 2 for facilities with 100,000 up to 475,000 lb/yr production because EPA was concerned about the number of commercial facilities estimated to experience compliance costs greater than 5% of revenues from aquaculture sales. EPA also determined that Option 3 would not be economically achievable for these facilities based on the high number of facilities estimated to experience compliance costs greater than the 10% revenue threshold. EPA selected Option 3 for facilities with greater than 475,000 lb/yr production because no facilities are estimated to experience compliance costs that exceed the 5% revenue threshold.

For more details about the BCT cost reasonableness test and the BAT analysis, see the economic and environmental assessment (USEPA, 2002).

Recirculating Systems

EPA proposes to establish BAT equal to BPT for recirculating systems. EPA proposed the most stringent option for facilities with recirculating systems. Because EPA projects limited economic impacts associated with the BPT requirements, EPA expects only limited economic impacts associated with BAT. For more details about the BCT and BAT economic analyses, see the economic and environmental assessment (USEPA, 2002).

*Net Pen S*ystems

EPA proposes to establish BAT equal to BPT for net pen systems. EPA has determined that no more stringent options representing BAT are available. For more details about the BCT and BAT economic analyses, see the economic and environmental assessment (USEPA, 2002).

2.2.3.3 NSPS

EPA is proposing new source performance standards that are identical to those proposed for existing dischargers that meet the 100,000 lb/yr production threshold. Engineering analysis indicates that the cost of installing pollution control systems during new construction is no more than the cost of retrofitting existing facilities and is frequently less than the retrofit cost. Because EPA projects the costs for new sources to be equal to or less than those for existing sources and because limited impacts are projected for these existing sources, EPA does not expect significant economic impacts (or barrier to entry) for new sources that meet the 100,000 lb/yr production threshold.

EPA is considering establishing new source performance standards for smaller coldwater CAAP facilities that produce between 20,000 and 100,000 lb/yr. EPA intends to conduct further analysis pertaining to this issue using detailed survey data.

Table 2.2-2. Summary of Proposed BPT Requirements for CAAP Facilities

System	*Description*	*TSS Numeric Limit*	*BMP Requirement*	*Reference*
Flow-through systems Full flow; 100,000 to 475,000 lb; includes treatment from OLSB that recombines with bulk flow	Combined or single discharge	Maximum monthly average: 6 mg/L Maximum daily average: 11 mg/L (Both are net concentrations)		451.11(b)(1) 451.11(c)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(d) 451.3(b)
	OR			
	Combined or single discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(d) 451.3(b)

System	Description	TSS Numeric Limit	BMP Requirement	Reference
Flow-through systems Separate OLSB discharge; 100,000 to 475,000 lb; facilities that discharge from OLSB separate to bulk discharge	OLSB discharge	Maximum monthly average: 67 mg/L Maximum daily average: 87 mg/L (Both are net concentrations)		451.11(b)(2) 451.11(c)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(d) 451.3(b)
	Bulk discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste Ensure staff are familiar with BMP plan	451.15(b) 451.15(d)
	OR			
	OLSB discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(d) 451.3(b)
	Bulk discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Ensure staff are familiar with BMP plan	451.15(b) 451.15(d)

System	Description	TSS Numeric Limit	BMP Requirement	Reference
Flow-through systems Full flow; more than 475,000 lb; includes treatment from OLSB that recombines with bulk flow	Combined or single discharge	Maximum monthly average: 6 mg/L Maximum daily average: 10 mg/L (Both are net concentrations)		451.11(a)(1) 451.11(c)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Develop and implement practices to minimize potential escape of nonnative species • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(c) 451.15(d) 451.3(b)
			Drugs and chemical reporting	451.3(a)
	OR			
	Combined or single discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Develop and implement practices to minimize potential escape of nonnative species • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(c) 451.15(d) 451.3(b)
			Drugs and chemical reporting	451.3(a)

System	*Description*	*TSS Numeric Limit*	*BMP Requirement*	*Reference*
Flow-through systems Separate OLSB discharge; more than 475,000 lb; facilities that discharge from OLSB separate to bulk discharge	OLSB discharge	Maximum monthly average: 55 mg/L Maximum daily average: 69 mg/L (Both are net concentrations)		451.11(a)(2) 451.11(c)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Develop and implement practices to minimize potential escape of nonnative species • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(c) 451.15(d) 451.3(b)
	Bulk discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste Ensure staff are familiar with BMP plan	451.15(b) 451.15(d)
			Drugs and chemical reporting	451.3(a)
	OR			
	OLSB discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Develop and implement practices to minimize potential escape of nonnative species • Ensure staff are familiar with BMP plan • Certify BMP plan	451.15(b) 451.15(c) 451.15(d) 451.3(b)
	Bulk Discharge		Develop BMP plan - management and removal of solids and excess feed	451.15(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste Ensure staff are familiar with BMP plan	451.15(b) 451.15(d)
			Drugs and chemical reporting	451.3(a)

System	Description	TSS Numeric Limit	BMP Requirement	Reference
Recirculating Systems More than 100,000 pounds annual production	All discharges	Maximum monthly average: 30 mg/L Maximum daily average: 50 mg/L		451.21
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Develop and implement practices to minimize potential escape of nonnative species • Ensure staff are familiar with BMP plan • Certify BMP plan	 451.25(b) 451.25(c) 451.25(d) 451.3(b)
			Drugs and chemical reporting	451.3(a)
	OR			
	All discharges		Develop BMP plan - management and removal of solids and excess feed	451.25(a)
			Develop BMP plan • Proper O&M of facility – Structural maintenance – Materials storage – Disposal of biological waste • Develop and implement practices to minimize potential escape of nonnative species • Ensure staff are familiar with BMP plan • Certify BMP plan	 451.25(b) 451.25(c) 451.25(d) 451.3(b)
			Drugs and chemical reporting	451.3(a)
Net Pen Systems All net pen systems with annual production more than 100,000 pounds, except those producing native species of salmon in AK	All discharges		Maintain real time monitoring system to monitor the rate of feed consumption through the detection of uneaten feed passing through the bottom of the net pen.	451.31
			Develop BMP plan • Minimize the discharge of net fouling organisms • Avoid the discharge of – Blood, viscera, fish carcasses, or transport water – Substances associated with in-place cleaning of nets • Develop and implement practices to minimize potential escape of nonnative species • Prohibited discharges: – Feed bags and other solid waste – Chemicals used to clean nets, boats or gear – Materials containing or treated with tributyltin compounds • Certify BMP plan	451.35 451.3(b)
			Drugs and chemical reporting	451.3(a)

2.3 REFERENCES

USEPA (U.S. Environmental Protection Agency). 2002. *Economic and Environmental Impact Analysis of Proposed Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Industry Point Source Category*. EPA 821-R-02-015. U.S. Environmental Protection Agency, Washington, DC.

CHAPTER 3
DATA COLLECTION ACTIVITIES

3.1 SUMMARY OF DATA COLLECTION ACTIVITIES

EPA collected data from a variety of sources to characterize the aquatic animal production (AAP) industry. The main purpose of EPA's data collection efforts was to obtain information on documented environmental impacts of concentrated aquatic animal production (CAAP) facilities, as well as additional data on CAAP waste characteristics, pollution prevention practices, wastewater treatment technology innovation, and facility management practices. EPA also engaged in other data collection activities, which included literature searches; a review of the Agency's Permit Compliance System (PCS), Discharge Monitoring Reports (DMRs), and National Pollutant Discharge Elimination System (NPDES) permits; a survey of the AAP industry; EPA site visit and wastewater sampling program; and meetings with industry experts and the public.

3.1.1 Literature Searches

EPA evaluated the following online databases to locate technical data and information to support regulatory development: the Agency's PCS database, Aquatic Sciences and Fisheries Abstracts' database, U.S. Department of Agriculture's (USDA) aquaculture literature database AGRICOLA, and the 1998 USDA Census of Aquaculture (USDA, 2000). In addition, the Agency conducted a thorough collection and review of secondary sources, which included technical journal articles; data, reports, and analyses published by government agencies; reports and analyses published by the AAP industry and its associated organizations; and publicly available financial information compiled by both government agencies and private organizations.

EPA used the documents cited above to develop the industry profile and a survey sampling frame, and to stratify the survey sampling frame. In addition to these publications, EPA examined many other documents that provided useful overviews and analyses of the AAP industry. EPA also conducted general Internet searches on many different technical components of the AAP industry.

EPA conducted several literature searches to obtain environmental impact information on various aspects of the AAP industry, including pollutants causing environmental impacts, water quality and ecological impacts from these pollutants, nonnative species impacts, and other potential impacts. EPA has included a summary of its environmental impact analysis in the public docket (USEPA, 2002a). This analysis, which EPA summarized in case studies, includes primary sources such as technical journal articles, newspaper articles, and comments and information from industry experts and government contacts for AAP.

EPA also conducted separate literature searches for case studies that characterize the AAP industry, including the typical effluents associated with different production system types and species. The primary sources for these case studies were technical journal articles, and comments and information from industry experts and government contacts for AAP.

3.1.2 Permitting Information

Permit Compliance System

EPA evaluated information from its PCS to identify CAAP industry point source dischargers with NPDES permits. EPA performed this initial analysis by searching the PCS, using the reported Standard Industrial Classification (SIC) codes used to describe the primary activities occurring at the site. Specifically, two SIC codes were used: 0273 (Animal Aquaculture) and 0921 (Fish Hatcheries and Preserves). Information obtained from this analysis is referred to in this document as the "PCS database."

EPA identified a total of 1,189 CAAP facilities in the PCS database. Based on the information in the database, an estimated 673 CAAP facilities have active NPDES permits. Some parameters found in the PCS data are parameters that the facility must report or monitor during use, but do not have established limits. Some parameters are monitored without set limits in order to enable the permitting authority to characterize the effluent and determine if continued monitoring is necessary. Other chemicals that appear in the PCS data have "report only" requirements where facilities report when they use specific chemicals or perform certain activities (such as cleaning tanks), which may only occur once or twice a year. Another group of parameters (such as flow, biomass, fish on hand, and fish food fed per day) are used by the permitting authority to characterize the volume of effluents and qualitative characteristics of the effluent and facility.

Table 3.1-1 provides a summary of parameters reported by CAAP facilities in the PCS database. Most facilities retrieved from the PCS are located in Florida, Idaho, Oregon, and Washington.

Discharge Monitoring Reports

EPA collected long-term effluent data from facility DMRs to supplement the PCS data in an effort to perform a "real world" check on the achievability of requirements of the proposed rule. DMRs summarize the quality and volume of wastewater discharged from a facility under an NPDES permit. DMRs are critical for monitoring compliance with NPDES permit provisions and for generating national trends on Clean Water Act compliance. DMRs may be submitted monthly, quarterly, or annually depending on the requirements of the NPDES permit. EPA developed a DMR database by collecting information from numerous CAAP facility DMRs and combining the information into a database for analysis. That database is referred to in this document as the "DMR database."

Table 3.1-1. Parameters in the PCS Database

Parameter
Ammonia
Backwash cycles
Biocides
Biochemical oxygen demand
Cadmium
Chemical oxygen demand
Chloramine
Chloride
Chlorophyll a
Coliform, fecal
Color
Conductivity
Copper
Diquat
Discharge event observation
Duration of discharge
E. coli
Fish food fed per day
Fish on hand
Floating solids or visible foam
Flow
Formalin (formaldehyde)
Hydrogen peroxide
Inorganic suspended solids
Lead

Parameter
Manganese
Nickel
Nitrogen[a]
Oil and grease
Outfall observation
Oxygen, dissolved
Ozone
pH
Phosphorus[a]
Potassium
Salinity
Silver
Sludge waste from secondary clarifiers
Solids, settleable
Solids, total dissolved
Solids, total suspended
Solids, volatile suspended
Stream flow
Temperature
Terramycin
Total production
Turbidity
WET test
Zinc

[a]Includes inorganic, organic, and total forms.

Indirect dischargers file compliance monitoring reports with their control authority (e.g., publicly owned treatment works (POTW)) at least twice per year as required under the General Pretreatment Standards (40 CFR Part 403). Direct dischargers file discharge monitoring reports with their permitting authority at least once per year. EPA did not collect compliance monitoring reports for CAAP facilities that are indirect dischargers because (1) a vast majority of CAAP indirect dischargers discharge small volumes of wastewater and do not discharge toxic compounds, (2) this information is less centralized and more difficult to collect, and (3) many of these indirect dischargers would not be considered significant industrial users (SIUs), and might not be subject to Part 403 requirements.

EPA was able to identify facility characteristics and evaluate DMR information from 57 flow-through facilities and 2 recirculating facilities. EPA collected 38,096 data points on 126 separate parameters (including nitrogen, phosphorus, solids, flow, chemicals such as formalin and diquat, and copper). Some parameters found in the DMR data are parameters that the facility must report or monitor during use, but do not have established limits. Some parameters are monitored without set limits in order to enable the permitting authority to characterize the effluent and determine if continued monitoring is necessary. Other chemicals that appear in the DMR data have "report only" requirements where facilities report when they use specific chemicals, which may only occur once or twice a year. Another group of parameters (such as flow, biomass, fish on hand, and fish food fed per day) are used by the permitting authority to characterize the volume of effluents and qualitative characteristics of the effluent and facility.

Table 3.1-2 provides a summary of the parameters found in the DMR database. Most facilities in the database are located in Idaho, Michigan, New York, Virginia, and Wisconsin.

Table 3.1-2. Parameters in the DMR Database

Parameter
Aluminum
Ammonia
Biochemical oxygen demand
Biomass
BOD, carbonaceous
Cadmium
Calcium carbonate
Chemical oxygen demand
Chloramine-T
Chlorophyll a
Chlorine
Coliform, fecal
Copper
Diquat
Dissolved oxygen
Duration of discharge
Fecal *Streptococcus*
Fish food fed per day
Fish on hand
Floating solids or visible foam-visual
Flow
Formalin (formaldehyde)
Hydrogen peroxide
Iron
Lead
Manganese
Nitrogen[a]
Oil and grease
Outflow during cleaning
Oxidation/reduction potential
Ozone
pH
Phosphorus[a]
Potassium permanganate
Roccal-II
Settleable solids
Silver
Sludge waste from secondary clarifiers
Solids, inorganic suspended
Solids, total dissolved
Solids, total suspended
Solids, volatile suspended
Sulfate, total
Temperature
Terramycin
Turbidity
Zinc

[a]Includes inorganic, organic, and total forms.

NPDES Permits

EPA reviewed over 170 NPDES permits and permit applications, provided by the Agency's regional offices, to obtain information on facility type, production methods and systems, species produced, and effluent treatment practices. EPA used this information as part of its initial screening process. The Agency identified types of CAAP facilities, including pond systems, flow-through systems, recirculating systems, and net pen systems, that might be covered under the proposed regulation. In addition, EPA used information from existing NPDES permits to better define the scope of the information collection requests and to supplement other information (e.g., DMR and PCS data) collected on waste management practices in the industry. EPA compiled the information from these permits into a database, which is referred to in this document as the "NPDES database."

EPA collected NPDES permits from 174 CAAP facilities. The following summaries characterize different aspects of the CAAP facilities in the NPDES database by facility location, type of ownership, production system types, and species types. EPA evaluated 174 NPDES permits from 37 states. Table 3.1-3 lists the number of NPDES permits (in the NPDES database) in each state.

Table 3.1-3. Number of Permitted Facilities by State

State	*No. of Permitted Facilities*
Alabama	1
Arizona	1
California	6
Colorado	2
Delaware	1
Hawaii	1
Iowa	4
Idaho	3
Illinois	1
Indiana	1
Kansas	2
Massachusetts	9
Maryland	7
Maine	7
Michigan	12
Minnesota	4
Missouri	6
Mississippi	2
North Carolina	4
North Dakota	6

State	No. of Permitted Facilities
Nebraska	4
New Hampshire	8
New Jersey	1
New York	15
Oregon	1
Rhode Island	7
South Carolina	1
South Dakota	2
Tennessee	6
Texas	9
Utah	1
Virginia	13
Vermont	5
Washington	2
Wisconsin	2
West Virginia	5
Wyoming	12
Total: 37 states	174

EPA classified each facility by type of ownership (government, private, or other), often determining the type of ownership by the name of the facility. Most of the facilities in the NPDES database are government facilities, with 117 of the 174 facilities. Fifty-six CAAP facilities were privately owned. Flow-through systems are the predominant system type in the NPDES database. EPA determined system type by searching for system descriptions in the permit, including diagrams showing specific facility components, and by analyzing information concerning outfalls. EPA determined the species type at each facility by finding specific mention of the species in the permit or attached documents. When the species type was unknown or different from the major species categories chosen (catfish, molluscs, perch, salmon, shrimp, striped bass, tilapia, or trout), EPA classified the species as “other.”

In addition, EPA categorized facilities with more than one species as “multiple.” Trout is the most common species represented in this database, with 63 facilities identified as producing this species. There are 42 facilities identified as producing multiple species, and 48 facilities identified as “other,” which is primarily game and sport fish.

Summary of NPDES, PCS, and DMR Data

EPA linked data from the NPDES database to the PCS and DMR databases. This provided the Agency with a description of the production systems and species at different facilities, as well as a characterization of the treatment systems at those facilities. This approach was useful for combining information from the databases to evaluate effluents from similar facilities. The linked data were used to evaluate permit limits for CAAP facilities.

3.2 SUMMARY OF AQUATIC ANIMAL PRODUCTION QUESTIONNAIRE ACTIVITY

EPA developed a survey questionnaire because the existing primary and secondary sources of information available to the Agency did not contain the information necessary to thoroughly evaluate regulatory options. In particular, EPA needs facility/site-specific technical and economic information to evaluate the costs and benefits of regulation.

3.2.1 Background

EPA published a notice in the *Federal Register* on September 14, 2000 (65 FR 55522), announcing its intent to submit the Aquatic Animal Production Industry Survey Information Collection Request (ICR) to the Office of Management and Budget (OMB). The September 14, 2000, notice requested comment on the draft ICR and the survey questionnaires. EPA received 44 sets of comments during the 60-day public comment period. Commenters on the ICR included the National Oceanic and Atmospheric Administration, U.S. Trout Farmers Association, American Farm Bureau Federation, North Carolina State University, Louisiana Rice Growers Association, Michigan Department of Natural Resources, Mississippi Farm Bureau Federation, Idaho Farm Bureau Federation, and Freshwater Institute. EPA made significant revisions to the survey methodology and questionnaires as a result of these public comments. The questionnaire was revised and divided into two survey versions. The first version is the screener survey (short version), and the second version is the detailed survey (the longer version). The two major reasons for the Agency's splitting the survey were (1) comments to the effect that the Agency would not know how much emphasis to place on rarely occurring facility types without a census and (2) the need to target specific types of CAAP facilities that could not be identified using information obtained from the databases available to the Agency at that time.

EPA published a second notice in the *Federal Register* on June 8, 2001 (66 FR 30902), announcing its intent to submit another Aquatic Animal Production Industry Survey ICR to OMB. The June 8, 2001, notice requested comment on the draft ICR and the detailed survey questionnaire. EPA received nine sets of comments during the 30-day public comment period. Commenters on the ICR included North Carolina Department of Agriculture and Consumer Services, Ohio Aquaculture Association, Catfish Farmers of America, National Aquaculture Association, National Association of State Aquaculture Coordinators, U.S. Trout Farmers Association, American Farm Bureau Federation, and Florida Department of Agriculture and Consumer Services.

EPA made every reasonable attempt to ensure that the AAP industry surveys did not request data and information currently available through existing sources of data. Before publishing the September 14, 2000, notice, EPA met with and distributed draft survey questionnaires to the Joint Subcommittee on Aquaculture, Aquaculture Effluents Task Force (JSA/AETF), which includes representatives from industry and trade associations, academia, and other interested stakeholders. After evaluating the comments received on the September 14, 2000, notice, EPA drafted a revised survey, and sent it to the

JSA/AETF for review and comment. EPA worked with the JSA/AETF through conference calls and written comments to further refine the detailed survey. EPA also conducted two conference calls with the economic technical subgroup of JSA/AETF to discuss the economic and financial questions in the survey. To the extent possible, EPA incorporated comments and suggestions from these initial reviews into the survey. EPA obtained approval from OMB for the use and distribution of the screener survey on August 1, 2001 (66 FR 64817) and for the detailed survey on November 28, 2001 (67 FR 6519).

3.2.2 Screener Survey

3.2.2.1 Description of the Screener Survey

In August 2001 EPA mailed a short screener survey, entitled *Screener Questionnaire for the Aquatic Animal Production Industry,* to approximately 6,000 AAP facilities. A copy of the screener survey is included in the record (USEPA, 2001). The screener survey consisted of 11 questions that solicited general facility information, including confirmation that the facility was engaged in aquatic animal production, species and size category produced, type of production system, wastewater disposal method, and total production at the facility in the year 2000. EPA used the information collected through the screener survey to describe industry operations and wastewater disposal practices. EPA also used the responses to the facility production question to classify each facility as small or not-small according to the Small Business Administration regulations at 13 CFR Part 121.

3.2.2.2 Development of Screener Survey Mailing List

The mailing list (sample frame) for EPA's screener survey was developed by synthesizing facility information from the Dunn and Bradstreet database, EPA's PCS, contacts with EPA regional permit writers, EPA site visits, state aquaculture contacts, universities, recent issues of *Aquaculture Magazine*, assistance from the Bureau of Indian Affairs on tribal facilities, and an extensive collection of Web sites with aquaculture references. Additionally, EPA requested, but was denied, access to the facility identification data associated with the USDA's 1998 Census of Aquaculture (USDA, 2000). The mailing list EPA developed contained approximately 6,000 facilities. This number seemed to compare favorably with the roughly 5,000 facilities in the 1998 Census of Aquaculture. EPA believes that the sample frame was as current as possible and reasonably complete, and minimized duplication.

Because approximately 90% of the facilities identified in EPA's mailing list were not classified by species of aquatic animal in production, the available database was not considered to be sufficient for purposes of selecting recipients for the detailed questionnaire. Again, the primary purpose of the screener survey was to collect this information.

3.2.2.3 Response to the Screener Survey

Although some 6,000 facilities received the screener survey, the total number of respondents was 3,273 and the number of respondents that actually produce aquatic animals was a little over 1,700. The discrepancy between the number of surveys sent and the number of facilities reporting they are aquatic animal producers is largely attributable to the fact that the list was compiled from general industry sources and included not only producers but also processors, retailers, and the like. The Agency believes that the facilities missed by its screener survey are likely to be small facilities that go into and out of business faster than can currently be tracked by sources outside the USDA, which has confidentiality agreements that do not allow the Department to share its information with EPA.

Because EPA intended to reduce the scope of the regulation by excluding these smaller facilities by production levels and species, the Agency sent the detailed survey to 263 facilities. Results of the screener survey were used to ensure that all of the facilities that received the detailed questionnaire produce aquatic animals and that a high percentage are conducting operations included in the scope of the proposed rule. Under the assumption that most of the facilities missing from the screener survey are small facilities, results from the 1998 Census of Aquaculture were used to assist the Agency in selecting appropriate sample sizes for each combination of production method and species.

3.2.2.4 Preliminary Summary of Data from the Screener Survey

The following summary of the results from the screener survey (Westat, 2002) is based on the 3,273 surveys that have been returned to EPA and analyzed (as of February 2002). Appendix A provides a detailed summary of the screener survey information. EPA will continue to process additional surveys and then analyze the complete data set. Of these 3,273 surveys, 1,747 respondents indicated that they produce aquatic animals at their facility. Table 3.2-1 is a summary of facilities that produce aquatic animals by region, based on screener survey data.

Table 3.2-1. Facilities Producing Aquatic Animals by Region[a]

Region	*Number of Facilities*	*Percentage of Facilities*
Southern	780	45%
Western	392	22%
North Central	292	17%
Northeastern	247	14%
Tropical	36	2%
Total	1,747	100%

[a] Regions are defined by categories from the USDA 1998 Census of Aquaculture (USDA, 2000).

States that are included within each of the USDA regions described above are summarized in Table 3.2-2.

Table 3.2-2. States Within Each USDA Region

Region	States
Southern	Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia
Western	Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming
North Central	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
Northeastern	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia
Tropical	Hawaii

Data from the survey indicate that ownership type is described as sole proprietorship for approximately 40% of facilities producing aquatic animals. An additional 15% are described as Subchapter S Corporations and 12% are identified as C Corporations. Overall, close to 80% of all facilities are under private ownership. A total of 13% of the facilities were described as state hatcheries, and another 3% were federal hatcheries. Approximately 77% of all facilities produce only one species, and 15% produce two species. Catfish production dominates the AAP industry in the United States; 31% of respondents indicated that they produce catfish. Other species produced are trout (28%), other finfish (19%), salmon (9%), and molluscan shellfish (9%). Pond systems are the most common production system in use with 61% of the respondents indicating the use of ponds. Table 3.2-3 summarizes production system data based on responses to the screener survey.

Table 3.2-3. Production Systems

System	Number of Facilities Using System[a]
Ponds	1,068
Flow-through raceways, ponds, or tanks	787
Recirculating systems	310
Net pens or cages	151
Floating or bottom aquaculture	144
Other	79

[a]Note: Some respondents indicated using more than one system type; therefore, the number of systems in this data set is greater than the number of facilities that reported producing aquatic animals.

3.2.3 Detailed Survey

3.2.3.1 Description of the Detailed Survey

EPA designed the detailed survey to collect site-specific technical and financial information from a representative sample of CAAP facilities. A copy of the detailed survey is included in the record (USEPA, 2002o). The detailed survey is divided into three parts. The first two parts collect general facility, technical, and cost data. The first set of questions in Part A request general facility site information, including facility contact information, facility size, and NPDES permit information. The general facility information questions also ask the site to identify and confirm that it is engaged in aquatic animal production. The second set of questions in Part A focuses on system descriptions and wastewater control technologies.

The detailed survey was mailed to concentrated aquatic animal producers shortly before the proposed regulation was signed. The data that will be collected by the detailed survey will be compiled and analyzed after the proposed rule has been published. The data will be noticed and made available for public comment in a Notice of Data Availability (NODA) that will be published in the *Federal Register*.

The wastewater control technology section is divided into six parts, one part for each type of production system (pond, flow-through, recirculating, net pens and cages, floating aquaculture and bottom culture, and other systems). The individual system sections have been tailored with specific questions and responses. Each of these sections asks the responder to describe (1) the system, (2) water use, (3) pollutant control practices, and (4) discharge characteristics.

Part B, the second part of the survey, asks the respondent for facility cost information. The cost information is intended to provide EPA with a complete description of all cost elements associated with the pollution control practices and technologies used at the facility. Separate tables show the details of capital and annual operating costs. The cost section also evaluates the current discharge monitoring practices, product losses, and feed information.

EPA will use the information from Part B to calculate the effluent limitations guidelines and standards and pollutant loadings associated with the regulatory options that the Agency considers for final rulemaking. The Agency also will use data received in response to these questions to identify treatment technologies in place; to determine the feasibility of regulatory options; and to estimate compliance costs, the pollutant reductions associated with the technology-based options, and potential environmental impacts associated with the regulatory options EPA considers for final rulemaking.

Part C, the third part of the detailed survey, elicits site-specific financial and economic data. EPA will use this information to characterize the economic status of the industry and to estimate potential economic impacts of wastewater regulations. The financial and economic information collected in the survey will be used to complete the economic analysis of the final effluent limitations guidelines and standards for the CAAP industry. EPA requested financial and economic information for the fiscal years ending 1999, 2000, and 2001—the most recent years for which data are available.

3.2.3.2 Sample Selection for the Detailed Survey

Respondents to the detailed questionnaire were selected at random from within groups (stratified random selection) that were identified using screener survey results. Based on the same screener survey results, along with design principles detailed in EPA's ICR, 263 facilities received the detailed questionnaire.

The sample and the questionnaires described above are expected to provide EPA with the minimum amount of information necessary to estimate the costs and benefits associated with regulatory options to be developed. These results will be noticed in the NODA, as mentioned above.

3.3 SUMMARY OF EPA'S SITE VISIT AND WASTEWATER SAMPLING PROGRAMS

3.3.1 Site Visits

During 2000 and 2001 EPA conducted site visits at 71 AAP facilities. The objectives of these site visits were (1) to collect information on aquatic animal operations, (2) to collect information on wastewater generation and waste management practices used by the AAP facilities, and (3) to evaluate each facility as a candidate for multi-day sampling.

In selecting candidates for site visits, EPA attempted to identify facilities representative of various AAP operations, as well as both direct and indirect dischargers. EPA specifically considered the type of aquatic animal production operation (production method and species produced), geographic region, age of the facility, size of facility (in terms of production), wastewater treatment processes employed, and best management practices (BMPs) and pollution prevention techniques used. EPA also solicited recommendations for facilities that perform well (e.g., facilities with advanced wastewater treatment technologies) from EPA regional offices, state agencies, and the JSA/AETF. The site-specific selection criteria are discussed in site visit reports prepared for the sites visited by EPA and are summarized in this document. The sites visited reflect a cross section of the industry that is fairly complete and proportionally representative of the AAP industry as a whole. EPA recognizes that a number of AAP facilities visited during the site visits are not CAAP facilities and would not be regulated under proposed rules. However, EPA was interested in collecting information from a wider range of AAP facilities than just CAAP facilities to evaluate the diversity of the AAP industry and to determine which segments should be included in proposed regulations.

During each site visit EPA collected information on the facility and its operations, including (1) general production data and information, (2) the types of aquatic animal production wastewaters generated and treated on-site, (3) water source and use, and (4) wastewater treatment and disposal operations.

EPA used the site visit reports to prepare sampling and analysis plans for each facility that would undergo multi-day sampling. For those facilities selected for sampling episodes, EPA also collected information on potential sampling locations for wastewater (raw influent, within the treatment system, and final effluent), as well as other information necessary for developing a sampling plan for possible multi-day sampling episodes. The purpose of the multi-day sampling was to characterize pollutants in raw wastewaters prior to treatment as well as to document wastewater treatment performance (including selected unit processes).

3.3.1.1 Site Visit Summary

Tables 3.3-1 and 3.3-2 summarize the different types of systems and species at the facilities that EPA visited to develop effluent guidelines for the CAAP industry.

Table 3.3-1. Summary of System Type Visited by EPA for the Development of Aquatic Animal Production Effluent Limitations Guidelines

System	*Number of Sites*
Pond	34
Flow-through	21
Net pen	5
Recirculating	7
Shellfish – bottom and off-bottom culture	5
Other	2
Total	74

Table 3.3-2. Summary of Species Visited by EPA for the Development of Aquatic Animal Production Effluent Limitations Guidelines

Species	*Number of Sites*	*Species*	*Number of Sites*
Catfish	11	Alligator	1
Trout	12	Yellow perch	2
Striped and hybrid striped bass	4	Soft-shell crab shedding	1
Tilapia	4	Salmon	10
Ornamental	9	Lobster	1
Crawfish	5	Chinese catfish	1
Molluscs	5	Mullet	1
Shrimp	7	Milkfish	1
Red snapper	1		

Table 3.3-3 describes the regional distribution of sites visited by EPA.

Table 3.3-3. Regional Distribution of Sites Visited

USDA Aquaculture Center Regions	*Number of Sites Visited*
Northeastern	11
North Central	6
Southern	37
Western	11
Tropical	6

Table 3.3-4 summarizes all of the sites visited, describing the geographic area, production systems used, and treatment technologies employed at the different facilities.

Table 3.3-4. Aquatic Animal Production Site Visit Summary

Date of Visit	*City*	*State*	*Species*	*Production System*	*Reference*
1/31/00	Stoneville	MS	Catfish	Ponds	USEPA, 2002b
1/31/00	Indianola	MS	Catfish	Ponds	USEPA, 2002c
1/31/00	Itta Bena	MS	Catfish	Ponds	USEPA, 2002d
2/1/00	Robert	LA	Tilapia	Recirculating system	USEPA, 2002e
2/1/00	Denham Springs	LA	Alligators	Other – alligator huts	USEPA, 2002f
2/2/00	Jeanerette	LA	Hybrid striped bass	Ponds	USEPA, 2002g
2/2/00	New Ibernia	LA	Crawfish	Ponds	USEPA, 2002h
2/2/00	New Ibernia	LA	Crawfish	Ponds	USEPA, 2002i
2/2/00	Abbeville	LA	Crawfish	Ponds	USEPA, 2002j
3/30/00	Richland	PA	Trout	Flow-through	USEPA, 2002k
3/30/00	Richland	PA	Trout	Flow-through	USEPA, 2002l
4/11/00	Brevard	NC	Trout	Flow-through	Tetra Tech, 2002a
4/11/00	Sapphire	NC	Trout	Flow-through	Tetra Tech, 2002b
4/12/00	Raleigh	NC	Tilapia	Recirculating system	Tetra Tech, 2002c
4/12/00	Plymouth	NC	Hybrid striped bass, crawfish	Ponds	Tetra Tech, 2002d
4/12/00	Plymouth	NC	Crawfish	Ponds	Tetra Tech, 2002e
4/13/00	Hertford	NC	Yellow perch, crab shedding, catfish	Ponds, tanks	Tetra Tech, 2002f
7/10/00	Buhl	ID	Trout	Flow-through	Tetra Tech, 2002g
7/10/00	Buhl	ID	Trout	Flow-through	Tetra Tech, 2002h
7/11/00	Twin Falls	ID	Trout	Flow-through	Tetra Tech, 2002i
7/11/00	Twin Falls	ID	Trout	Flow-through	
7/11/00	Twin Falls	ID	Trout	Ponds, flow-through	Tetra Tech, 2002j
7/12/00	Seattle	WA	Salmon	Net pens	Tetra Tech, 2002k
7/12/00	Puget Sound	WA	Salmon	Net pens	
7/12/00	Bainbridge	WA	Salmon	Net pens	
7/14/00	Bow	WA	Molluscan shellfish - oysters	Flow-through, bottom culture	Tetra Tech, 2002l
7/23/00	Blacksburg	VA	Tilapia, hybrid striped bass, yellow perch	Recirculating system	USEPA, 2002m
11/27/00	Turners Falls	MA	Hybrid striped bass	Recirculating system	Tetra Tech, 2002m
11/28/00	Mt. Desert	ME	Salmon, mussels	Net pens, off-bottom hanging culture (mussels)	Tetra Tech, 2002n
11/29/00	Birch Harbor	ME	Lobster	Other - pounds	Tetra Tech, 2002o

Date of Visit	City	State	Species	Production System	Reference
11/30/00	Eastport	ME	Salmon	Net pens	Tetra Tech, 2002p
1/2/01	Honolulu	HI	Ornamentals, seaweed	Flow-through	
1/2/01	Honolulu	HI	Tilapia, Chinese catfish	Net pen in pond	
1/2/01	Honolulu	HI	Ornamentals	Flow-through	
1/2/01	Honolulu	HI	Shrimp	Flow-through	
1/8/01	Honolulu	HI	Shrimp, ornamentals, mullett, milkfish, red snapper	Flow-through	
1/10/01	Kauai	HI	Shrimp	Flow-through	
1/25/01	Lakeland	FL	Ornamentals	Ponds	Tetra Tech, 2002q
1/25/01	Gibsonton	FL	Ornamentals	Ponds	Tetra Tech, 2002r
1/25/01	Ruskin	FL	Ornamentals	Ponds, recirculating systems	Tetra Tech, 2002s
1/25/01	Ruskin	FL	Ornamentals	Ponds	Tetra Tech, 2002t
1/26/01	Homestead	FL	Ornamentals	Flow-through tanks, low flow rate	Tetra Tech, 2002u
1/26/01	Miami	FL	Ornamentals	Recirculating, flow-through tanks w/ low flow rate	Tetra Tech, 2002v
3/15/01	Greensboro	AL	Catfish	Ponds	Tetra Tech, 2002w
3/16/01	Gallion	AL	Catfish	Ponds	Tetra Tech, 2002w
3/17/01	Greensboro	AL	Catfish	Ponds	Tetra Tech, 2002w
3/18/01	Greensboro	AL	Catfish	Ponds	Tetra Tech, 2002w
3/19/01	Greensboro	AL	Catfish	Ponds	Tetra Tech, 2002w
3/20/01	Greensboro	AL	Catfish	Ponds	Tetra Tech, 2002w
4/5/01	East Orland	ME	Salmon - native endangered species	Flow-through	Tetra Tech, 2002x
4/5/01	Ellsworth	ME	Salmon - native endangered species	Flow-through	Tetra Tech, 2002y
4/6/01	Solon	ME	Salmon	Flow-through	Tetra Tech, 2002z
4/6/01	North Anson	ME	Brook trout, landlocked salmon (coho, chinook)	Flow-through	Tetra Tech, 2002aa
4/6/01	Augusta	ME	Brook trout, lake trout, splake	Flow-through	Tetra Tech, 2002aa
7/16/01	Harrietta	MI	Rainbow trout, brown trout	Flow-through	Tetra Tech, 2002bb
7/16/01	Beulah	MI	Landlocked salmon	Flow-through	Tetra Tech, 2002cc
7/17/01	Palmyra	WI	Rainbow trout	Flow-through, earthen raceways	Tetra Tech, 2002dd
7/17/01	Dodgeville	WI	Baitfish, various species of sport fish	Ponds	Tetra Tech, 2002ee

Date of Visit	City	State	Species	Production System	Reference
7/18/01	Osage Beach	MO	Various warmwater species (including bluegill, catfish, paddlefish)	Ponds	Tetra Tech, 2002ff
7/19/01	Renville	MN	Tilapia	Recirculating system	Tetra Tech, 2002gg
7/30/01	Los Fresnos	TX	Shrimp	Ponds	Tetra Tech, 2002hh
7/31/01	San Benito	TX	Shrimp	Ponds	Tetra Tech, 2002hh
7/31/01	San Perlita	TX	Shrimp	Ponds	Tetra Tech, 2002hh
7/31/01	Rio Hondo	TX	Shrimp	Ponds	Tetra Tech, 2002ii
8/1/01	Lonoke	AR	Baitfish	Ponds	Tetra Tech, 2002jj
8/1/01	Lonoke	AR	Baitfish	Ponds	Tetra Tech, 2002jj
8/1/01	Lonoke	AR	Baitfish	Ponds	Tetra Tech, 2002jj
8/1/01	Cabot	AR	Baitfish	Ponds	Tetra Tech, 2002jj
8/1/01	Hazon	AR	Baitfish	Ponds	Tetra Tech, 2002jj
8/2/01	DeValls Bluff	AR	Baitfish	Ponds	Tetra Tech, 2002kk
12/11/01	Baltimore	MD	Multiple	Recirculating	Tetra Tech, 2002ll

Note: "QZ" means quiescent zone; "OLSB" means offline settling basin.

3.3.1.2 Comparison of Site Visit Data with 1998 Aquaculture Census

EPA compared the distribution of system types visited by the Agency with percentage of system types reported in the 1998 Aquaculture Census (USDA, 2000). Relative to the national distribution of production systems as reported by the Aquaculture Census, EPA visited proportionately more net pens and flow-through systems and fewer pond systems. Data from the 1998 Aquaculture Census suggest that about 63% of the aquatic animal production is in ponds, 14% in flow-through systems, 4% in net pens and cages, 7% in recirculating systems, 7% in bottom shellfish culture, and 5% in other systems. Of the systems EPA visited, 46% were ponds, 28% flow-through systems, 7% net pens and cages, 9% recirculating systems, 7% bottom shellfish culture, and 3% other systems.

3.3.2 Wastewater Sampling

Based on data collected from the site visits, EPA selected three facilities (two flow-through systems, sampling episodes 6297 and 6460, and one recirculating system, sampling episode 6439) for multi-day sampling. Selection of the facilities was based on an analysis of information collected during the site visits, as well as the following criteria: (1) the facility performed operations representative of CAAP facilities, (2) and the facility used in-process and/or end-of-pipe treatment practices that EPA was considering for technology option selection.

The Agency collected the following types of information during each sampling episode: (1) dates and times of sample collection; (2) flow data corresponding to each sample; (3) production data corresponding to each sample; (4) design and operating parameters for source reduction, recycling, and treatment; (5) technologies characterized during sampling; (6) information about site operations that had changed since the site visit or had not been included in the site visit report; and (7) the temperature, pH, and dissolved oxygen of the sampled waste streams.

Data collected from the sampling episodes contributed to characterization of the industry, development of the list of pollutants of concern, and development of raw wastewater characteristics. EPA used the data collected from the influent, intermediate, and effluent points to analyze the efficacy of treatment at the facilities and to develop current discharge concentrations, loadings, and the treatment technology options for the CAAP industry. EPA also used effluent data to calculate the long-term averages and limitations for each of the proposed regulatory options. EPA will also use industry-provided data from the AAP detailed survey (USEPA, 2002o) to complement the sampling data for these calculations. During each sampling episode, EPA also collected flow rate data corresponding to each sample collected and production information from each associated production system for use in calculating pollutant loadings and production-normalized flow rates. EPA has included in the public record all information collected for which the facility has not asserted a claim of Confidential Business Information (CBI) or which would indirectly reveal information claimed to be CBI.

After the conclusion of the sampling episodes, EPA prepared sampling episode reports for each facility, which included descriptions of the wastewater treatment processes, sampling procedures, and analytical results. EPA documented all data collected during sampling episodes in the sampling episode report for each sampled site; the reports are in the AAP Administrative Record. Nonconfidential business information from these reports is available in the public record for this proposal. For detailed information on sampling and preservation procedures, analytical methods, and quality assurance/quality control procedures, refer to the quality assurance project plan (Tetra Tech, 2000a) and sampling and analysis plans (Tetra Tech, 2000b; Tetra Tech 2001a; Tetra Tech 2001b) completed for the sampling visits.

3.3.2.1 Pollutants Sampled

During each multi-day sampling episode, facility influent and effluent waste streams were sampled. Samples were also collected at intermediate points throughout the wastewater treatment system to assess the performance of individual treatment units. Sampling episodes were conducted over a 12-hour or 24-hour period, depending on the production system being analyzed. Samples were obtained using a combination of composite and grab samples. EPA had the samples analyzed for a variety of conventional compounds (5-day biochemical oxygen demand, total suspended solids, oil and grease, and pH), nonconventional compounds (nutrients, microbiological contaminants, drugs, and chemicals), and toxic compounds (metals and organics). When possible for a given parameter, EPA collected 24-hour composite samples to capture the variability in the waste streams generated throughout the day (e.g., production wastewater during feeding and non-feeding periods).

Table 3.3-5 lists the pollutants for which EPA sampled at the three sites. Tables 3.3-6, 3.3-7, and 3.3-8 summarize the metal, volatile organic, and semivolatile organic analytes sampled at all three visited sites.

Table 3.3-5. Sampling Analytes

Pollutant	***Sampling Episode***		
	6297	***6439***	***6460***
Settleable solids	✓	✓	✓
pH	✓	✓	✓
Biochemical oxygen demand (BOD)	✓	✓	✓
Total suspended solids (TSS)	✓	✓	✓
Chloride	✓	✓	✓
Total dissolved solids (TDS)	✓	✓	✓
Total volatile solids	✓	✓	✓
Total phosphorus	✓	✓	✓
Dissolved phosphorus	✓	✓	✓
Orthophosphate	✓	✓	✓
Ammonia as nitrogen	✓	✓	✓
Total Kjeldahl nitrogen (TKN)	✓	✓	✓
Nitrate/nitrite	✓	✓	✓
Chemical oxygen demand (COD)	✓	✓	✓
Total organic carbon (TOC)	✓	✓	✓
Oil and grease (n-hexane extractable material)	✓	✓	✓
Sulfate	✓	✓	✓
Metals	✓	✓	✓
Volatile organics	✓	✓	✓
Semivolatile organics	✓	✓	✓
Oxytetracycline	✓		
Total coliforms		✓	✓
Fecal coliform		✓	✓
Fecal *Streptococcus*		✓	✓
Aeromonas		✓	✓
Mycobacterium marinum		✓	✓
Escherichia coli		✓	✓
Enterococcus faecium		✓	✓
Toxicity: Fathead minnow, *Pimephales promelas*	✓	✓	
Toxicity: Cladoceran, *Ceriodaphnia dubia*	✓	✓	
Toxicity: Green alga, *Selenastrum capricornutum*	✓	✓	

Note: A checkmark (✓) means that the listed pollutant was sampled for at that site.

Table 3.3-6. Metal Analytes

Metal Analytes		
Aluminum	Cobalt	Selenium
Antimony	Copper	Thallium
Arsenic	Iron	Silver
Barium	Lead	Sodium
Beryllium	Magnesium	Tin
Boron	Manganese	Titanium
Cadmium	Mercury	Vanadium
Calcium	Molybdenum	Yttrium
Chromium	Nickel	Zinc

Table 3.3-7. Volatile Organic Analytes

Volatile Organic Analytes		
Acetone	Dibromochloromethane	Isobutyl alcohol
Acrolein	1,2-Dibromoethane	Methacrylonitrile
Acrylonitrile	Dibromomethane	Methylene chloride
Allyl alcohol	trans-1,4-Dichloro-2-Butene	Methyl ethyl ketone
Benzene	1,1-Dichloroethane	Methyl methacrylate
Bromodichloromethane	1,2-Dichloroethane	4-Methyl-2-Pentanone
Bromoform	1,1-Dichloroethene	1,1,1,2-Tetrachloroethane
Bromomethane	trans-1,2-Dichlorethene	1,1,2,2-Tetrachloroethane
Carbon disulfide	1,2-Dichloropropane	Tetrachloroethane
Carbon tetrachloride	1,3-Dichloropropane	Toluene
Chloroacetonitrile	cis-1,3-Dichloropropene	1,1,1-Trichloroethane
Chlorobenzene	trans-1,3-Dichloropropene	1,1,2-Trichloroethane
2-Chloro-1,3-Butadiene (chloroprene)	Diethyl ether	Trichloroethene
Chloroethane	*p*-Dioxane	Trichlorofluoromethane
2-Chloroethylvinyl ether	Ethylbenzene	1,2,3-Trichloropropane
Chloroform	Ethyl cyanide	Vinyl acetate
Chloromethane	Ethyl methacrylate	Vinyl chloride
3-Chloropropene	2-Hexanone	*m*-Xylene
Crotonaldehyde	Iodomethane	*o*- and *p*-Xylene

Table 3.3-8. Semivolatile Organic Analytes

Semivolatile Organic Analytes		
Acenaphthene	7, 12-Dimethylbenz(a)anthracene	2-Nitrophenol
Acenaphthylene	3,6-Dimethylphenanthrene	4-Nitrophenol
Acetophenone	2,4-Dimethylphenol	2-Nitroaniline
Alpha-terpineol	Di-n-butyl phthalate	3-Nitroaniline
4-Aminobiphenyl	1,4'-Dinitrobenzene	Nitrobenzene
Aniline	2,4-Dinitrophenol	5-Nitro-o-toluidine
Aniline, 2,4,5-trimethyl-	2,4-Dinitrotoluene	N,N-Dimethylformamide
Anthracene	2,6-Dinitrotoluene	N-Nitrosodiethylamine
Aramite	Di-n-octyl phthalate	N-Nitrosodimethylamine
Benzanthrone	Di-n-propylnitrosamine	N-Nitrosodi-n-butylamine
Benzenethiol	Diphenyl ether	N-Nitrosodiphenylamine
Benzidine	Diphenylamine	N-Nitrosomethyl-ethylamine
Benzo(a)anthracene	Diphenyldisulfide	N-Nitrosomethyl-phenylamine
Benzo(a)pyrene	1,2-Diphenylhydrazine	N-Nitrosomorpholine
Benzo(b)fluoranthene	2,6-Di-tert-butyl-p-benzoquinone	N-Nitrosopiperidine
Benzo(g,h,i)perylene	Ethane, pentachloro-	o-Anisidine
Benzo(k)fluoranthene	Ethyl methanesulfonate	o-Cresol
2,3-Benzofluorene	Ethylenethiourea	o-Toluidine
Benzoic acid	Fluoranthene	o-Toluidine, 5-Chloro
Benzonitrile, 3, 5-Dibromo- 4-Hydroxy-	Fluorene	p-Chloroaniline
Benzyl alcohol	Hexachlorobenzene	p-Cresol
Beta-Naphthylamine	Hexachlorobutadiene	p-Cymene
Biphenyl	Hexachlorocyclopentadiene	p-Dimethylamino-azobenzene
Bis(2-chloroethoxy)methane	Hexachloroethane	Pentachlorobenzene
Bis(2-chloroethyl)ether	Hexachloropropene	Pentachlorophenol
Bis(2-chloroisopropyl)ether	Hexanoic acid	Pentamethylbenzene
Bis(2-ethylhexyl)phthalate	Indeno(1,2,3-cd)pyrene	Perylene
1-Bromo-2-Chlorobenzene	Isophorone	Phenacetin
1-Bromo-3-Chlorobenzene	2-Isopropylnaphthalene	Phenanthrene
4-Bromophenyl, phenyl ether	Isosafrole	Phenol
Butyl benzyl phthalate	Longifolene	Phenol, 2-methyl-4,6-Dinitro
Carbazole	Malachite green	Phenothiazine
4-Chloro-3-Methylphenol	Mestranol	1-Phenylnaphthalene
4-Chloro-2-Nitroaniline	Methapyrilene	2-Phenylnaphthalene
1-Chloro-3-Nitrobenzene	Methyl methanesulfonate	2-Picoline
2-Chloronaphthalene	2-Methylbenzothioazole	P-Nitroaniline

Semivolatile Organic Analytes		
2-Chlorophenol	3-Methylcholanthrene	Pronamide
4-Chlorophenyl phenyl ether	4,5-Methylene-phenanthrene	Pyrene
Chrysene	4,4-Methylene-bis(2-Chloroaniline)	Pyridine
Crotoxyphos	1-Methylfluorene	Resorcinol
Dibenzo(a,h)anthracene	2-Methylnaphthalene	Safrole
Dibenzofuran	1-Methylphenanthrene	Squalene
Dibenzothiophene	2-(Methylthio)-benzothiazole	Styrene
1,2-Dibromo-3-Chloropropane	Naphthalene	1,2,4,5-Tetra-chlorobenzene
1,3-Dichloro-2-Propanol	1,5-Naphthalenediamine	2,3,4,6-Tetrachlorophenol
2,6-Dichloro-4-Nitroaniline	1,4-Naphthoquinone	Thianaphthene
2,3-Dichloroaniline	1-Naphthylamine	Thioacetamide
1,2-Dichlorobenzene	n-C10 (n-decane)	Thioxanthe-9-one
1,3-Dichlorobenzene	n-C12 (n-dodecane)	Toluene, 2,4-Diamino-
1,4-Dichlorobenzene	n-C14 (n-tetradecane)	1,2,3-Trichlorobenzene
3,3'-Dichlorobenzidine	n-C16 (n-hexadecane)	1,2,4-Trichlorobenzene
2,3-Dichloronitro-benzene	n-C18 (n-octadecane)	2,3,6-Trichlorophenol
2,4-Dichlorophenol	n-C20 (n-eicosane)	2,4,5-Trichlorophenol
2,6-Dichlorophenol	n-C22 (n-docosane)	2,4,6-Trichlorophenol
1,2:3,4-Diepoxybutane	n-C24 (n-tetracosane)	1,2,3-Trimethoxybenzene
Diethyl phthalate	n-C26 (n-hexacosane)	Triphenylene
3,3'-Dimethoxybenzidine	n-C28 (n-octacosane)	Tripropyleneglycolmethyl ether
Dimethyl phthalate	n-C30 (n-triacontane)	1,3,5-Trithiane
Dimethyl sulfone	4-Nitrobiphenyl	—

3.3.2.2 Analytical Methods

The Agency collected, preserved, and transported all samples according to EPA protocols as specified in the Sampling and Analysis Plan (Tetra Tech, 2000b; Tetra Tech, 2001a; Tetra Tech, 2001b) for each facility and in the AAP Quality Assurance Project Plan (QAPP) (Tetra Tech, 2000a).

EPA collected composite samples for most parameters because the Agency expected the wastewater composition to vary over the course of a day. The Agency collected grab samples from unit operations for oil and grease and microbiological contaminants (e.g., total and fecal coliform bacteria, fecal *Streptococcus*, *Aeromonas*, *Mycobacterium arinum*, *Escherichia coli*, and *Enterococcus faecium*). Composite samples were collected either manually or by using an automated sampler. Individual aliquots for the composite samples were collected at least once every 4 h over each 12-h period or 24-h period. Samples for oil and grease were collected two or three times per day, every 4 h, and microbiological samples were collected once a day.

EPA contract laboratories completed all wastewater sample analyses, except for the field measurements of temperature, dissolved oxygen, and pH. EPA or facility staff collected field measurements of temperature, dissolved oxygen, and pH at the sampling sites. The analytical chemistry methods used, as well as the sample volume requirements, detection limits, and holding times, were consistent with the laboratory's quality assurance and quality control plan. Laboratories contracted for AAP sample analysis followed EPA-approved analysis methods for all parameters.

The EPA contract laboratories reported data on their standard report sheets and submitted them to EPA's sample control center. The center reviewed the report sheets for completeness and reasonableness. EPA reviewed all reports from the laboratory to verify that the data were consistent with requirements, reported in the appropriate units, and in compliance with the applicable protocol.

A description of the analytical methods and nominal quantitation limits is available in Appendix B. Quality control measures used in performing all analyses complied with the guidelines specified in the analytical methods and in the AAP QAPP (Tetra Tech, 2000a). EPA reviewed all analytical data to ensure that these measures were followed and that the resulting data were within the QAPP-specified acceptance criteria for accuracy and precision.

3.4 U.S. Department of Agriculture Data

3.4.1 1998 Census of Aquaculture

The 1998 Census of Aquaculture was the first national census taken for the AAP industry. Conducted by USDA's National Agricultural Statistics Service (NASS), this census was a response to a need for accurate measurements of the rapidly growing aquaculture industry. The industry had grown from $45 million for value of products sold in 1974 to more than $978 million in 1998 (USDA, 2000).

The 1998 Census of Aquaculture was conducted to expand the aquaculture data collected in the 1997 Census of Agriculture. The Census of Aquaculture collected detailed information on on-site aquaculture practices, size of operation based on water area, production, sales, method of production, sources of water, point of first sale outlets, cooperative agreements and contracts, and aquaculture products distributed for conservation and recreation (USDA, 2000). The Census was conducted using mailed questionnaires, follow-up telephone calls, and personal interviews.

EPA used the 1998 Census of Aquaculture to develop the production rate thresholds. Six production size categories, based on revenue classifications used in the 1998 Census of Agriculture, were used to group facility production data reported in the screener surveys:

- National 1: $1,000 to $24,999
- National 2: $25,000 to $49,999
- National 3: $50,000 to $99,999
- National 4: $100,000 to $499,999

- National 5: $500,000 to $1,000,000
- National 6: more than $1,000,000

EPA collected data from a review of USDA's 1998 Census of Aquaculture data and used these data to define model CAAP facilities for estimating national compliance costs. The data were also used to determine estimates of pollutant loads, discharge volumes, BMPs and treatment technologies currently in use, and the applicability of BMPs and treatment technologies.

3.4.2 National Agricultural Statistics Service

In addition to the Census of Aquaculture, EPA also evaluated data from the USDA's NASS to characterize current trends in AAP production in the United States by evaluating data on inventory and sales by size category for catfish and trout, the two leading sectors in the AAP industry.

Before the Census, NASS tracked the catfish and trout industry through reports on monthly catfish processing, reports on quarterly catfish production, and annual catfish and trout surveys (USDA, 2000). The first catfish processing reports were published in February 1980. Surveys for catfish production were also initiated in 1980 but were then discontinued in 1982 because of funding shortages. Currently, the NASS catfish production survey is conducted twice a year in Mississippi, Alabama, Arkansas, and Louisiana and annually in nine additional states.

3.4.3 Animal and Plant Health Inspection Service: Veterinary Services and the National Animal Health Monitoring System

The Animal and Plant Health Inspection Service (APHIS) has conducted several studies, which EPA used to characterize production practices in the AAP industry. A 1995 report, *An Overview of Aquaculture in the United States* (USDA, 1995), describes the diverse U.S. aquaculture industry, reviews trends in industry development, and discusses regulatory complexities facing the industry. EPA reviewed this report to develop a more comprehensive understanding of the AAP industry in the United States and develop industry profiles for various species.

The National Animal Health Monitoring System (NAHMS) is sponsored by USDA through the APHIS's Veterinary Services (VS). VS collaborated with USDA's NASS to implement a two-part study of foodsize catfish producers in Alabama, Arkansas, Louisiana, and Mississippi. The first part of the study, *Catfish '97: Part I: Reference of 1996 U.S. Catfish Health and Production Practices* (USDA, 1997a), provides information on disease and production of foodsize catfish. The second part of the study, *Catfish '97: Part II*, *Reference of 1996 U.S. Catfish Management Practices* (USDA, 1997b), describes catfish production management practices. EPA reviewed both studies to collect information to develop the catfish industry profile.

EPA used information from NAHMS to further characterize the catfish industry in the United States and describe current disease management issues and practices. (Refer to Chapter 4, Industry Profiles, for more information on the catfish sector of the AAP industry.)

3.4.4 Economic Research Service

The U.S. Department of Agriculture's Economic Research Service (ERS) publishes *Aquaculture Outlook*, a semi-annual report that analyzes aquaculture imports and exports and consumption of aquaculture products in the United States. EPA used data from this report to evaluate trends in markets for AAP products and to develop a description of factors that affect the AAP industry and influence domestic AAP markets, including competition from international competitors. Species covered in the report include catfish, trout, tilapia, salmon, shrimp, molluscs, and ornamental fish.

3.5 SUMMARY OF OTHER DATA SOURCES

Other data sources used to characterize the AAP industry include information from the Joint Subcommittee on Aquaculture, BMP guidance documents developed by governmental and other organizations, data from the Small Business Advocacy Review Panel, and public participation.

3.5.1 Joint Subcommittee on Aquaculture

The Joint Subcommittee on Aquaculture (JSA) serves as a federal interagency coordinating group to increase the overall effectiveness and productivity of federal aquaculture research, transfer, and assistance programs. Membership includes the U.S. Secretary of Agriculture, the U.S. Secretary of Commerce, the U.S. Secretary of the Interior, the U.S. Secretary of Energy; the U.S. Secretary of Health and Human Services, the Administrator of the Environmental Protection Agency, the Chief of Engineers, the Administrator of the Small Business Administration, the Administrator of the Agency for International Development, the Chairman of the Tennessee Valley Authority, the Director of the National Science Foundation, the Governor of the Farm Credit Administration, and the other heads of federal agencies as appropriate. JSA is a statutory committee that operates under the aegis of the National Science and Technology Council (NSTC) of the Office of Science and Technology Policy in the Office of the Science Advisor to the President. JSA reports to the NSTC's Committee on Science, which is one of five research and development committees NSTC has established to prepare strategies and budget recommendations for accomplishing national goals.

JSA's Aquaculture Effluents Task Force, created in September 1999, assisted EPA in the development of effluent guidelines by gathering technical information to develop industry profiles and assess regulatory options. The Task Force convened a Technical Information Exchange Forum hosted by the Department of Commerce, National Oceanic and Atmospheric Administration. The Forum included the participation of each of the Task Force's 14 technical subgroups. EPA consulted with JSA's Task Force throughout the effluent guideline development process. The Task Force provided a vehicle for coordinating and facilitating stakeholder input, and its participants represented a range of interests, experiences, and expertise in the AAP industry.

3.5.2 BMP Guidance Documents Developed by Governmental and Other Organizations

A number of states, including Alabama, Arizona, Arkansas, Florida, Hawaii, and Idaho, were found to have recommended BMPs for AAP. In addition, BMPs have also been developed for specific types of aquatic species. BMPs are addressed in manuals or regulations, depending on the state. Data were collected from in-house resources and through Internet research and might not represent every state that has developed BMPs for AAP.

3.5.2.1 Alabama

Dr. Claude Boyd and his colleagues, with funding from the Alabama Catfish Producers (a division of the Alabama Farmers Federation), has developed a set of BMPs for aquaculture facilities in Alabama. The BMPs are described in a series of guide sheets that have been adopted by USDA's Natural Resources Conservation Service (NRCS) to supplement the Service's technical standards and guidelines (Auburn University and USDA, 2002). The NRCS technical standards are intended to be referenced in Alabama Department of Environmental Management rules or requirements that are promulgated for aquaculture in Alabama. The guide sheets address a variety of topics, including reducing storm runoff into ponds, managing ponds to reduce effluent volume, erosion control in watersheds and on pond embankments, settling basins and wetlands, and feed management.

3.5.2.2 Arizona

Arizona's BMPs for feeding operations regulation covers aquaculture facilities classified as feeding operations for purposes of regulation of discharge water quality (ARS 49-245-47; Section 318 CWA).

The Arizona Department of Environmental Quality has rules that regulate aquaculture through three general, goal-oriented BMPs. These BMPs address manure handling, including harvesting, stockpiling, and disposal; treatment and discharge of aquaculture effluents containing nitrogenous wastes; and closing of aquaculture facilities when they cease operation (Fitzsimmons, 1999).

Compliance with these BMPs is intended to minimize the discharge of nitrates from facilities without being too restrictive for farm operations. The draft document *Arizona Aquaculture BMPs* describes BMPs that can minimize nitrogen impacts from aquaculture facilities. A list of information resources is also provided for additional information about Arizona aquaculture and BMPs (Fitzsimmons, 1999).

3.5.2.3 Arkansas

The Arkansas Bait and Ornamentals Fish Growers Association (ABOFGA, n.d.) developed a list of BMPs to help its members make their farms more environmentally friendly. More specifically, the Association provides a set of BMPs that help to conserve water, reduce effluent, capture solids, and manage nutrients. Members may voluntarily agree to adopt the BMPs on their farms (ABOFGA, n.d.).

3.5.2.4 Florida

Florida's aquaculture certificate of registration and BMP regulation requires any person engaging in aquaculture to be certified by the Florida Department of Agriculture and Consumer Services and to follow BMPs (Ch 5L-3.003, 5L-3). *Aquaculture Best Management Practices*, a manual prepared by the department, establishes BMPs for aquaculture facilities in Florida. By legislative mandate (Chapter 5L-3), the BMPs in the manual are intended to preserve environmental integrity, while eliminating cumbersome, duplicative, and confusing environmental permitting and licensing requirements. When these BMPs are followed, aquaculturists meet the minimum standards necessary for protecting and maintaining offsite water quality and wildlife habitat. All certified aquaculturists are required to follow the BMPs in Chapters II through X of the manual, which address federal permitting; construction; compliance monitoring; shipment, transportation, and sale; water resources; nonnative and restricted nonnative species; health management; mortality removal; and chemical and drug handling (FDACS, 2000).

3.5.2.5 Hawaii

Hawaii recently developed a practical BMP manual to assist aquaculture farmers in managing their facilities more efficiently and complying with discharge regulations. The manual, *Best Management Practices for Hawaiian Aquaculture* (Howerton, 2001), is available from the Center for Tropical and Subtropical Aquaculture.

Hawaii is also developing a BMP for traditional use of a *loko kuapa*-style Hawaiian fish pond. Because of changes in the land tenure, decreases in native population, total loss of traditional pond management practices, and benign neglect, fishpond production has declined in Hawaii. Although Hawaii's fishpond production efficiency is too low to justify the economic cost, Hawaii is making major efforts to restore and put into service several of these traditional structures as sustainable development demonstrations and as opportunities for maintaining ties to a nearly extinct element of cultural heritage (SOEST, n.d.).

3.5.2.6 Idaho

In combination with site-specific information, *Idaho Waste Management Guidelines for Aquaculture Operations* can be used to develop a waste management plan to meet water quality goals. Such a waste management plan would address Idaho's water quality concerns associated with aquaculture in response to the Clean Water Act and Idaho's Water Quality Standards and Wastewater Treatment Requirements. The manual is also intended to assist aquaculture facility operators in developing BMPs to maintain discharge levels that do not violate the state's water quality standards (IDEQ, n.d.).

3.5.2.7 Other BMP Guidance Documents

BMPs have also been developed for specific species, including shrimp, hybrid striped bass, and trout. The Global Aquaculture Alliance, in *Codes of Practice for Responsible Shrimp Farming*, has compiled nine recommended codes of practice that are intended to serve as guidelines for parties who want to develop more specific national or regional codes of practice or formulate systems of BMPs for use on shrimp farms. These codes of practice address a variety of topics, including mangroves, site evaluation, design and construction, feeds and feed use, shrimp health management, therapeutic agents and other chemicals, general pond operations, effluents and solid wastes, and community and employee relations (Boyd, 1999). The purpose of the document is to provide a framework for environmentally and socially responsible shrimp farming that is voluntary, proactive, and standardized. The document also provides a background narrative that reviews the general processes involved in shrimp farming and the environmental and social issues facing the industry (Boyd, 1999).

The Hybrid Striped Bass Industry: From Fish Farm to Consumer is a brochure that provides guidance to new and seasoned farmers in the proper handling of fish from the farm to the consumer. Although the brochure is primarily geared toward providing quality fish products to consumers, the information it provides about the use of drugs and chemicals, including pesticides and animal drugs and vaccines, could be used to benefit the environment (Jahncke et al., 1996).

The Trout Producer Quality Assurance Program of the U.S. Trout Farmer's Association (USTFA) is a two-part program that emphasizes production practices that enable facilities to decrease production costs, improve management practices, and avoid any possibilities of harmful drug or other chemical residues in fish. Part 1 discusses the principles of quality assurance, and Part 2 provides information about the highest level of quality assurance endorsed by the USTFA. Although the program addresses a variety of subjects related to trout production, the discussion on waste management and drugs and chemicals can be applied to protecting the environment (USTFA, 1994).

3.5.3 Other Industry-Supplied Data: Small Business Advocacy Review Panel

EPA collaborated with the Small Business Advocacy Review Panel (SBAR), which convened on the proposed effluent limitations guidelines and standards for the CAAP industry. Section 609(b) of the Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement Fairness Act of 1996, requires that a panel be convened prior to publication of the Initial Regulatory Flexibility Analysis that an agency may be required to prepare under the RFA.

The Panel, with input from Small Entity Representatives (SERs), analyzed issues related to small entities. These issues included an estimate of the number of small entities to which the proposed rule will apply; a description of reporting, record keeping, and other compliance requirements and an estimate of the classes of small entities that may be subject to the requirements; identification of federal rules that might duplicate, overlap, or conflict with the proposed rule; alternatives to the proposed rule that accomplish the stated objectives and minimize significant economic impacts of the proposed rule on small entities; and any impacts on small entities.

Before convening the Panel, EPA had several discussions, meetings, and conference calls with small entities that will potentially be affected by the proposed rule. Between August and October 2001, EPA held discussions with members of JSA’s Aquaculture Effluents Task Force (AETF) to identify potential SERs. EPA invited 16 aquatic animal producers and two university professors to serve as potential SERs for the pre-panel outreach process. In November 2001, EPA mailed a packet of background materials about the rulemaking process to potential SERs. On December 12, 2001, EPA held a meeting/conference call in Washington, DC, with small entities potentially affected by the proposed rule. The SERs provided comments on materials provided by EPA. Their comments were used to update existing information collected by EPA and to revise the proposed regulatory options for the CAAP industry.

A Panel Report is included in the public record supporting this rulemaking (USEPA, 2002n) and can be accessed on-line at http://www.epa.gov/ost/guidance/aquaculture/.

3.5.4 Summary of Public Participation

The public participated in the rulemaking process through several mechanisms, such as public meetings, outreach to AAP industry representatives, conference calls, and information exchange by mail.

EPA encouraged the participation of all interested parties throughout the development of the proposed CAAP effluent limitations guidelines and standards. EPA conducted outreach to the major trade associations through the JSA/AETF (whose membership includes producers, trade associations, federal and state agencies, and academic and environmental organizations). EPA also participated in seven JSA/AETF meetings and gave presentations on the status of the regulation development. In addition, EPA met with environmental groups, including the Natural Resources Defense Council, SeaWeb, and Environmental Defense, concerning this proposal.

When the CAAP industry was first identified as a candidate for rulemaking, EPA met with industry associations and environmental groups and representatives from state and local governments to solicit their opinions on the issues that the Agency should consider as it moved toward rulemaking.

In the development of the surveys, which were used to gather facility-specific information on this industry, EPA consulted with the various JSA/AETF technical subgroups to ensure that the information was requested in an understandable manner and that the information would be available in the form requested.

EPA and representatives from USDA, FDA, and DOI held meetings to discuss this regulation. EPA met with USDA's APHIS to discuss how APHIS and the industry might be affected by or affect requirements on the CAAP industry implemented by EPA in this rule. EPA and the FDA's Center of Veterinary Medicine met to discuss the new drug approval process and with Fish and Wildlife Service representatives to discuss aquatic nuisance species and the regulatory authority various agencies have over such species. EPA also met with representatives from state and local governments to discuss their concerns regarding aquatic animal production facilities and how EPA should approach these facilities in regulation.

3.6 REFERENCES

ABOFGA (Arkansas Bait and Ornamental Fish Growers Association). n.d. *Best Management Practices (BMP's) for Baitfish and Ornamental Fish Farms*. Arkansas Bait and Ornamental Fish Growers Association, in cooperation with the University of Arkansas at Pine Bluff, Aquaculture/Fisheries Center.

Auburn University and USDA (U.S. Department of Agriculture). 2002. Alabama Aquaculture BMP Fact Sheets, No. 1-15. Alabama Natural Resources Conservation Service, Montgomery, AL. <http://www.al.nrcs.usda.gov/sosections/Engineering/BMPIndex.html>. Accessed May 2002.

Boyd, C.E. 1999. *Codes of Practice for Responsible Shrimp Farming*. Global Aquaculture Alliance, St. Louis, Missouri. 48 pp. <http://www.GAAlliance.org>.

FDACS (Florida Department of Agriculture and Consumer Services). 2000. *Aquaculture Best Management Practices*. Florida Department of Agriculture and Consumer Services, Division of Aquaculture, Tallahassee, FL.

Fitzsimmons, K. 1999. *Draft: Arizona Aquaculture BMPs*. Arizona Department of Environmental Quality. <http://www.ag.arizona.edu/azaqua/bmps.html>. Accessed September 25, 2001.

Howerton, R. 2001. *Best Management Practices for Hawaiian Aquaculture*. Center for Tropical and Subtropical Aquaculture, University of Hawaii Sea Grant Extension Services, Publication No. 148.

IDEQ (Idaho Department of Environmental Quality). n.d. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

Jahncke, M.L, T.I.J. Smith, and B.P, Sheehan. 1996. *The Hybrid Striped Bass Industry: from Fish Farm to Consumer.* U.S. Department of Agriculture, FISMA Grant No. 12-25-G-0131. U.S. Department of Commerce, National Marine Fisheries Service, South Carolina Department of Natural Resources, and South Carolina Department of Agriculture.

SOEST (School of Ocean and Earth Science and Technology, Hawaii Sea Grant). n.d. *Development of a Best Management Practice for Traditional Use of A Loko Kuapa Style Hawaiian Fishponds*. School of Ocean and Earth Science and Technology, Hawaii Sea Grant. <http://www.soest.hawaii.edu/SEAGRANT/AQ/AQ4.htm>. Accessed October 2001.

Tetra Tech, Inc. 2000a. *Aquatic Animal Production Industry Quality Assurance Project Plan*. Tetra Tech, Inc., Fairfax, VA.

Tetra Tech, Inc. 2000b. Sampling and Analysis Plan for Clear Springs Foods, Inc., Box Canyon Facility, Buhl, ID.

Tetra Tech, Inc. 2001a. Sampling and Analysis Plan for Fins Technology, Turner Falls, MA.

Tetra Tech, Inc. 2001b. Sampling and Analysis Plan for Harrietta Hatchery, Harrietta, MI.

Tetra Tech, Inc. 2002a, August. Site visit report for Cantrell Creek Trout Farm, Brevard, NC.

Tetra Tech, Inc. 2002b, August. Site visit report for Sweetwater Trout Farm, Sapphire, NC.

Tetra Tech, Inc. 2002c, August. Site visit report for Lake Wheeler Road Agriculture Facility, Raleigh, NC.

Tetra Tech, Inc. 2002d, August. Site visit report for Vernon James Research and Extension Center, Plymouth, NC.

Tetra Tech, Inc. 2002e, August. Site visit report for Mill Pond Crawfish Farm, Plymouth, NC.

Tetra Tech, Inc. 2002f, August. Site visit report for Aubrey Onley, Hertford, NC.

Tetra Tech, Inc. 2002g, August. Site visit report for Clear Springs Foods, Inc., Box Canyon Facility, Buhl, ID.

Tetra Tech, Inc. 2002h, August. Site visit report for Clear Springs Foods, Inc., Snake River Facility, Buhl, ID.

Tetra Tech, Inc. 2002i, August. Site visit report for Pisces Investments, Magic Springs Facility, Twin Falls, ID.

Tetra Tech, Inc. 2002j, August. Site visit report for Bill Jones Facility, Twin Falls, ID.

Tetra Tech, Inc. 2002k, August. Site visit report for Rich Passage, Seattle, WA.

Tetra Tech, Inc. 2002l, August. Site visit report for Taylor Industries, Bow, WA.

Tetra Tech, Inc. 2002m, August. Site visit report for Fins Technology, Turner Falls, MA.

Tetra Tech, Inc. 2002n, August. Site visit report for Acadia Aquaculture, Mt. Desert, ME.

Tetra Tech, Inc. 2002o, August. Site visit report for DB Rice Fisheries, Birch Harbor, ME.

Tetra Tech, Inc. 2002p, August. Site visit report for Heritage Salmon, Eastport, ME.

Tetra Tech, Inc. 2002q, August. Site visit report for Interstate Tropical Fish Hatchery, Lakeland, FL.

Tetra Tech, Inc. 2002r, August. Site visit report for EkkWill Waterlife Resources, Gibsonton, FL.

Tetra Tech, Inc. 2002s, August. Site visit report for Norton’s Tampa Bay Fisheries, Ruskin, FL.

Tetra Tech, Inc. 2002t, August. Site visit report for University of Florida Tropical Aquaculture Lab, Ruskin, FL.

Tetra Tech, Inc. 2002u, August. Site visit report for Angel's Hatchery, Homestead, FL.

Tetra Tech, Inc. 2002v, August. Site visit report for Lebaco Enterprises, Inc., Miami, FL.

Tetra Tech, Inc. 2002w, August. Site visit report for Alabama Catfish Industry, Greensboro, AL.

Tetra Tech, Inc. 2002x, August. Site visit report for Craig Brook National Fish Hatchery, East Orland, ME.

Tetra Tech, Inc. 2002y, August. Site visit report for Greenlake National Fish Hatchery, Ellsworth, ME.

Tetra Tech, Inc. 2002z, August. Site visit report for Atlantic Salmon of Maine, Solon, ME.

Tetra Tech, Inc. 2002aa, August. Site visit report for Embden Rearing Station and Governor Hill Hatchery, Augusta, ME.

Tetra Tech, Inc. 2002bb, August. Site visit report for Harrietta Hatchery, Harrietta, MI.

Tetra Tech, Inc. 2002cc, August. Site visit report for Platte River Hatchery, Beulah, MI.

Tetra Tech, Inc. 2002dd, August. Site visit report for Rushing Waters Fisheries, Inc., Palmyra, WI.

Tetra Tech, Inc. 2002ee, August. Site visit report for Gollon Brothers, Dodgeville, WI.

Tetra Tech, Inc. 2002ff, August. Site visit report for Osage Catfisheries, Osage Beach, MO.

Tetra Tech, Inc. 2002gg, August. Site visit report for MinnAqua Fisheries Facility, Rennville, MN.

Tetra Tech, Inc. 2002hh, August. Site visit report for Harlingen Shrimp Farm, Arroyo Aquaculture Association, and Loma Alta, Los Fresnos, TX.

Tetra Tech, Inc. 2002ii, August. Site visit report for Southern Star Shrimp Farm, Rio Hondo, TX.

Tetra Tech, Inc. 2002jj, August. Site visit report for Arkansas Baitfish Association, Lonoke, AR.

Tetra Tech, Inc. 2002kk, August. Site visit report for Harry Saul Minnow Farm, DeValls Bluff, AR.

Tetra Tech, Inc. 2002ll, August. Site visit report for Baltimore Aquarium, Baltimore, MD.

USDA (U.S. Department of Agriculture). 1995. *Overview of Aquaculture in the United States*. U.S. Department of Agriculture, Animal and Plant Health Information Services, Centers for Epidemiology and Animal Health, Fort Collins, CO.

USDA (U.S. Department of Agriculture). 1997a. *Catfish NAHMS '97, Part I: Reference of 1996 U.S. Catfish Health & Production Practices*. Centers for Epidemiology and Animal Health, USDA/APHIS, Fort Collins, CO.

USDA (U.S. Department of Agriculture). 1997b. *Catfish NAHMS '97, Part II: Reference of 1996 U.S. Catfish Management Practices*. Centers for Epidemiology and Animal Health, USDA/APHIS, Fort Collins, CO.

USDA (U.S. Department of Agriculture). 2000. *The 1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agriculture Statistics Service, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2001. *Screener Questionnaire for the Aquatic Animal Production Industry*. OMB Control No. 2040-0237. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002a. *Economic and Environmental Impact Analysis of Proposed Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Industry Point Source Category*. EPA 821-R-02-015. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002b, August. Site visit report for National Warmwater Aquaculture Center, Stoneville, MS.

USEPA (U.S. Environmental Protection Agency). 2002c, August. Site visit report for Delta Western, Indianola, MS.

USEPA (U.S. Environmental Protection Agency). 2002d, August. Site visit report for America's Catch, Itta Bena, MS.

USEPA (U.S. Environmental Protection Agency). 2002e, August. Site visit report for Til-Tech, Robert, LA.

USEPA (U.S. Environmental Protection Agency). 2002f, August. Site visit report for Alagri, Denham Springs. LA.

USEPA (U.S. Environmental Protection Agency). 2002g, August. Site visit report for Westover Farms, Jeanerette, LA.

USEPA (U.S. Environmental Protection Agency). 2002h, August. Site visit report for Durand Brothers Crawfish Farms, New Ibernia, LA.

USEPA (U.S. Environmental Protection Agency). 2002i, August. Site visit report for Glen Dugas Crawfish Farm, New Ibernia, LA.

USEPA (U.S. Environmental Protection Agency). 2002j, August. Site visit report for David LaCour Crawfish Farm, Abbeville, LA.

USEPA (U.S. Environmental Protection Agency). 2002k, August. Site visit report for Arrowhead Springs, Richland, PA.

USEPA (U.S. Environmental Protection Agency). 2002l, August. Site visit report for Limestone Springs, Richland, PA.

USEPA (U.S. Environmental Protection Agency). 2002m, August. Site visit report for Virginia Tech Aquaculture Center, Blacksburg, VA.

USEPA (U.S. Environmental Protection Agency). 2002n. *Final Report of the Small Business Advocacy Review Panel on EPA's Planned Proposed Rule: Effluent Limitations Guidelines and Standards for the Aquatic Animal Production Industry*. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002o. *Detailed Questionnaire for the Aquatic Animal Production Industry*. OMB Control No. 2040-0240. U.S. Environmental Protection Agency, Washington, DC.

USTFA (U.S. Trout Farmer's Association). 1994. *Trout Producer Quality Assurance Program*. U.S. Trout Farmer's Association, Charles Town, WV.

Westat. 2002. *Preliminary Statistics from Aquaculture Questionnaires: Summary Statistics Report*. February 6, 2002. Westat, Inc., Rockville, MD.

CHAPTER 4
INDUSTRY PROFILES

4.1 OVERVIEW OF THE INDUSTRY

Aquaculture in the United States began in the 1850s as a commercial enterprise when fish culturists developed the technology needed to spawn and grow brook trout. Several culturists who became proficient in fish raising techniques found that they could sell their fish for a profit (Stickney, 2000b). Today, the aquaculture industry in the United States encompasses the production of finfish, shellfish, crustaceans, reptiles, other aquatic animals, and aquatic plants. These plants and animals are produced for a variety of reasons, including as food, pets, bait, and sportfish; for ornamental and display purposes; as research and test organisms; and to enhance natural populations. EPA has broadly defined aquatic animal production (AAP) to include any production of aquatic animals and is not including aquatic plant production in the definition. The following chapter describes aquatic animal production in the United States, including systems used to produce aquatic animals and many of the aquatic animals produced.

As valuable commercial fisheries began to decline in the latter half of the 19th century, there was a growing concern about the stock depletion. Spencer F. Baird, who was affiliated with the Smithsonian Institute, worked with Congress to create a federal fisheries agency (Stickney, 2000b). The nation's first federal conservation agency, the U.S. Fish & Fisheries Commission, was established in 1871. Known today as the National Marine Fisheries Service, the agency is responsible for marine commercial fisheries, while the U.S. Fish and Wildlife Service (USFWS) is responsible for freshwater fish, whose use is primarily recreational. The two agencies share responsibility for anadromous fish such as chinook and coho salmon.

After the U.S. Fish & Fisheries Commission was established, fish culture activities developed quickly. By the end of 1871, 11 states had established fish commissions; by 1877 there were fish commissions in 26 states. To further expand fish culture activities, Baird instructed Livingston Stone to set up an egg collection facility in California on the McCloud River. Prior to this facility, fish culturists transported fish via the newly established transcontinental railway from the east to the west coast. The striped bass and the American shad became most successful (Hartman and Preston, 2001). These species were exported around the world as well. Many people were optimistic that the work of artificial propagation of foodfishes, the introduction of promising exotic species, and the redistribution of native fishes to new waters could ensure an increased and sustainable food production in the nation's natural water bodies, in particular the Great Lakes and the oceans.

The goals of public fish hatcheries, often referred to as conservation hatcheries, differ from the goals of private commercial fish hatcheries. Conservation hatcheries produce fish for stocking in public waters to enhance or restore recreational or commercial fisheries. Private, for-profit hatcheries produce fish for several purposes, including food, bait, use in the aquarium trade, and use in stocking private waters (Westers, 2001). Generally, public hatcheries focus on the "wild" qualities of the fish produced. Fish produced for enhancement purposes are produced to retain genetic integrity and characteristics needed to survive in the wild. On the other hand, most private hatcheries focus on maximum production to meet economic goals. Commercial producers emphasize genetic selection for fast growth and adaptation to culture conditions. These differences in goals are reflected in the variety of production strategies generally applied by public and private programs.

4.1.1 Development of Federal, State, and Local Hatchery Programs

Expansion continued and by 1949, 46 of the states counted a total of 522 hatcheries, while the federal system had 99 hatcheries in 43 states. At the same time, however, stocking programs came under scrutiny. Stocking of fingerling-size trout had replaced the early fry stocking programs, but even fingerling stocking, in most instances, produced dismal returns. At the same time, angling pressure increased. To meet angler demand many states launched into stocking catchable-size trout. It was now possible to feed the fish dry prepared diets, giving hatcheries the opportunity to greatly expand production in terms of biomass and numbers. This expansion required greater hatchery capacity.

Public fish hatcheries became extremely popular with the public at large, as many became favored places to visit. Such facilities became firmly entrenched in local communities, making it politically difficult to discontinue their operations. Hatcheries attracted not only tourists, but also people interested in sportfishing opportunities, especially the stocking of catchable trout.

Both state and federal governments established research facilities, which made significant contributions to the advancement of fish culture in the United States. State fish hatchery facilities made significant advances in developing of prepared feeds, identifying diseases and treatments, advancing engineering design for water systems, and identifying or developing methods to measure and control water quality (Stickney, 2000b).

In 1973, the Endangered Species Act became a catalyst for shifting the goals of some public hatcheries from stocking sport fish to propagating endangered and threatened species. Today the USFWS considers its primary responsibility to be fish resource restoration and maintenance, while the states' responsibility is to supply fish for the enhancement of sportfishing opportunities. As a consequence, many federal hatchery facilities have either been closed or transferred to the state.

Currently, 28 USFWS hatcheries are involved in the restoration of threatened or endangered species. Maintaining the genetic integrity of these aquatic organisms is considered a high priority (Hartman and Preston, 2001). Despite this goal, 49 states use nonnative sport fish species, and some states rely entirely on nonnative species for recreational sportfishing (Schramm and Piper, 1995).

An example of a successful state hatchery program is the restoration of red drum in the Gulf of Mexico. The Texas Parks and Wildlife Department releases 20–30 million juvenile red drum fingerlings annually into coastal bays (Pennell et al., 2001). It has been estimated that since 1990, the abundance of red drum 1 to 5 years of age is double the population prior to the 1980s. The success of this fishery might also have been affected by the closing of the commercial fishery in 1981 when red drum was declared a game fish.

Both federal and state hatcheries serve as a tool for fisheries management to develop and maintain recreational, commercial, and tribal fisheries; supply year-classes to supplement natural reproduction; introduce new species; and restore endangered or threatened species.

Put-and-take stocking, or stocking that increases angler opportunities through the release of harvestable-size fish, is still an important activity in many state hatchery programs. State hatcheries stocked more than 60 million catchable trout in 1980. That same year the federal hatchery system released 11.9 million catchable trout. Coldwater fish make up the largest stocking program; 252 state and 36 federal hatcheries produce salmonids. More than 500 million coldwater fish are stocked annually, and according to Radonski and Martin (1986), this number falls 38 million short of the amount required to meet angler demands. Most salmonids stocked are Pacific salmon species released as smolts into various river systems connected to the Pacific Ocean. In the Columbia River Basin, more than 90 state and federal hatcheries raise and release some 190 million juvenile Pacific salmon annually (Schramm and Piper, 1995).

Total estimated production of all salmonid species for stocking in public waters is 35–42 million pounds annually. In terms of numbers of fish stocked on an annual basis, coolwater fish, including walleye, northern pike, and yellow perch, are the most abundant. At least 47 states have programs for stocking coolwater fish. In the 1983–1984 season, over 1 billion walleye fry were stocked in the United States, followed by 42 million northern pike and 13 million yellow perch. Finally, approximately 43 states have warmwater stocking programs for primarily largemouth bass. Other warmwater fish species stocked to restore or enhance fisheries are smallmouth bass, bluegill, sunfish, crappies, striped bass, hybrid striped bass, channel catfish, flathead catfish, and blue catfish (Smith and Reeves, 1986).

4.1.2 Development of Commercial Aquatic Animal Production

Commercial foodfish production in the United States began to grow in the 1960s. Before that time, AAP was generally limited to trout production. The trout industry in Idaho began to expand, as did production of warmwater species in southern states, particularly catfish production (Stickney, 2000b). Interest in commercial AAP gained popularity at several universities, including the University of Washington and Auburn University. The expansion of faculties' expertise and research activities in commercial AAP led to an increased body of knowledge about fish life cycles, production methods, and husbandry practices. Commercial AAP benefited from new research activities and strong university programs. In the mid-1980s, the U.S. Department of Agriculture (USDA) created five regional aquaculture centers that represent the Western, North Central, Southern, Northeastern, and Tropical/Subtropical Regions. Building on academic interest in commercial AAP and state and federal hatchery experiences, commercial foodfish production in the United States has grown over the past 30 years.

Idaho dominates trout production with cultured rainbow trout. Relying on cold spring water, the trout industry has been developed primarily around the Magic Valley region of Idaho using water from subterranean rivers (Stickney, 2000b). Initiated by research at USFWS laboratory facilities in Stuttgart, Arkansas, and in Marion, Alabama, channel catfish became the dominant species for production in the southern United States. Although the catfish industry was originally centered in Arkansas, falling water tables in the early 1970s limited expansion potential. Instead, catfish farmers moved to the Mississippi Delta region with its flat topography and shallow water table. Today Mississippi leads catfish production in the United States; however, catfish are produced in all southern states. Limited catfish production occurs in other states, such as California and Idaho. Though once considered of interest as food only in southern states, today the catfish industry has developed a national market through an aggressive marketing campaign (Stickney, 2000b). In addition to trout and catfish, other freshwater fish and shellfish are also raised commercially in the United States, including hybrid striped bass, tilapia, and crawfish.

Salmon production developed in the 1970s in Puget Sound, Washington, with the production of pan-sized coho. Research to expand net pen production originally focused on coho and chinook. Researchers, charged with maintaining threatened native stocks of Atlantic salmon in Maine, experimented with producing Atlantic salmon in the Pacific Northwest and discovered that Atlantic salmon were better suited for production in captivity than salmon species indigenous to the Pacific. Today, salmon culture continues to grow in Maine, whereas in Washington salmon production has leveled off and even declined in recent years. Salmon net pen culture is illegal in Oregon and Alaska; however, salmon ranching, the production of smolts for release and recapture as adults, is permitted.

Commercial marine fish production in the United States remains limited. A few commercial facilities produce red drum in Texas, and there are a few commercial operations for the production of summer flounder (Stickney, 2000b). Marine shrimp culture is well established in the United States; Texas is the leading producer. Some mollusc production, including oysters, mussels, and clams, occurs on the Atlantic, Gulf of Mexico, and Pacific coasts of the United States.

4.2 SYSTEM TYPES

4.2.1 Ponds Systems

4.2.1.1 Levee Ponds[1]

Regions of the United States with relatively flat land and sufficient clay in the soils are usually well suited for constructing levee ponds for producing aquatic animals. A levee pond is constructed by creating earthen levees from excess soil that is covering the future pond bottom. It can be constructed as a single unit or as a singular part of a group of ponds in which the levees often serve as common walls for more than one pond. The tops

[1] Some of the information for this section was adapted from T. Wellborn and M. Brunson, *Construction of Levee-type Ponds for Fish Production*, publication no. 101 (Southern Regional Aquaculture Center, Stoneville, Mississippi, 1997).

of levees are maintained, at least on one side, so that the operator can move equipment and vehicles along the pond bank for feeding and harvesting. Assistance in pond design and construction is sometimes available from local offices of the USDA's Natural Resources Conservation Service.

Water supplies for levee ponds are typically wells, located on-site at a facility. Some facilities rely on pumped or free-flowing water from surface water bodies such as lakes, streams, or coastal waters. Those relying on surface waters, however, must be careful not to introduce undesirable species or organisms into the culture ponds. Water might need to be screened or filtered as it is pumped into the pond. Rainwater falling directly on the pond is also captured and can be a source for maintaining water levels. For those systems that rely on well water, water conservation and rainwater capture are important management tools to minimize pumping costs.

Like watershed ponds, the size and shape of levee ponds are determined by the available land, its topography, and its underlying soils. Levee pond size varies from less than 1 to more than 25 acres, but most ponds for foodfish production are 4 to 16 acres. Smaller ponds may be used for broodstock holding and fry or seed production because they are easier to manage for these purposes than larger ponds. Larger levee ponds are typically more difficult to manage and harvest than smaller ones, but they are more economical to construct. The average depth of a levee pond is about 4 to 5 feet.

Drainage structures on a levee pond have two functions. The first is to provide a conveyance for overflow, which regulates the water level in the pond. If a pond captures excessive rainfall, the overflow structure allows the excess water to drain before it overflows the levees that enclose the pond. In some pond facilities (e.g., baitfish facilities), overflow pipes connect the ponds so water can be transferred between adjacent ponds to conserve water.

The second function of drainage structures is to allow the complete draining of the pond. The drainpipe is located in one of the levee walls just below the grade of the pond bottom. Some ponds have a drainage structure that functions as both an overflow control and a drain. For example, the structure can be in the form of a standpipe that swivels or a riser structure. Other ponds have separate overflow pipes and drains. If the drain has a valve, the valve remains closed at all times until the pond is drained.

In catfish ponds, which represent more than half of the ponds in production in the United States, as well as other high-density production ponds such as ponds for hybrid striped bass and shrimp, the use of mechanical aeration is common throughout the growing season. Stationary mechanical aerators are strategically positioned in the pond to maintain sufficient dissolved oxygen levels throughout the entire pond. In the event of extreme low-oxygen conditions, supplemental emergency aeration might be required. Emergency aeration is usually provided by using tractor-driven mechanical aerators.

Fish harvest takes place using seines that can be stretched across the entire pond. The mesh size of the seine allows smaller fish to escape to be harvested at a later date. After being seined into a section of the pond, the fish are removed from the pond with a net attached to a scale and boom. After being simultaneously removed and weighed, the fish are loaded into live haul trucks for shipment to a processing facility.

Levee ponds are the most commonly used method of production for channel catfish. Hybrid striped bass and shrimp are also commonly grown in levee ponds. Any species amenable to pond culture can be grown in a levee pond; for example, crawfish, shrimp, baitfish, ornamentals, sport fish, and perch. The following are some examples of different production practices in levee ponds:

> *Channel catfish*. Channel catfish fingerlings are produced in nursery ponds, which are smaller than production ponds. Feed-trained fry are stocked into the ponds, usually in the spring of the year. These ponds are managed to ensure that plankton blooms are also available as a source of natural food until the fry become proficient at using the artificial diet as their sole source of food. Fingerlings are grown in the ponds for about 5 to 9 months and then harvested by seining during the colder seasons and transferred to growout ponds. The nursery pond is eventually drained, and any remaining fish are killed to prevent cannibalism of the fry by larger fish.
>
> Foodfish production varies among farms, but it can involve crops of single cohorts or multiple cohorts. For the single-cohort cropping system, fingerlings are stocked, grown to market size, and then harvested. The pond is cleaned of all fish (by draining or killing the remaining fish), and a new cohort is put into the pond to repeat the cycle. Multiple cohorts can be cropped by selectively harvesting larger fish and understocking with fingerlings. This approach allows the operator to use most of the water for many years between draining events.
>
> Both fingerlings and foodfish are typically fed with mechanical feeders that blow the feed across the surface of the pond. With respect to stocking density, producers usually try to achieve a maximum biomass of about 6,000 lb/ac. Mechanical aeration is required to maintain adequate water quality and oxygen levels in the ponds. Most catfish farmers use paddlewheel aerators to supply sufficient aeration for production.[2]
>
> *Penaeid shrimp*. Levee ponds are also commonly used for the production of penaeid shrimp. The ponds are filled in the spring of each year, and the larval shrimp are stocked in the ponds. The shrimp are fed by broadcasting feed into the ponds with mechanical feeders or by hand feeding out of a boat criss-crossing the pond. Shrimp production ponds are also aerated to maintain sufficient levels of dissolved oxygen. After the shrimp are harvested in the fall, the ponds are drained and left to dry. This oxidizes the organic matter and reduces the likelihood of disease problems from growing season to growing season. Most shrimp facilities use surface water as a source and screen the inlets to prevent predators from entering the ponds. Because many of the shrimp grown in the United States are nonnative species, escapement and disease are concerns for regulatory agencies. Outlets are screened to prevent escapement. Water is reused by draining it to ditches and pumping or conveying it back into the ponds from the ditches.

[2] Information adapted from C. Tucker, Channel Catfish Culture, in the *Encyclopedia of Aquaculture*, 2000. ed. R.R. Stickney, pp. 153-170. John Wiley and Sons, NY.

Crawfish. Levee ponds are also used in crawfish production. Managing crawfish production ponds is different from managing other pond production systems. Crawfish ponds are shallow, with an average depth of 18 to 24 in. They are drained every spring to begin the reproduction process. As the water is drained from the ponds, the crawfish burrow into the pond bottom and produce their young. A forage crop is planted to provide food for the crawfish when the ponds are flooded in the fall; rice is a common forage crop. After the growing season, the rice is harvested, and the rice stubble is left in the field. The field is then flooded to a depth of about 1.5 ft. The crawfish come out of their burrows and feed on the decaying vegetation. Crawfish are harvested by using baited traps.

4.2.1.2 Watershed Ponds[3]

In much of the United States, watershed ponds are built to capture storm water runoff, which serves as the primary water supply for the pond. Although often not ideal for use as AAP ponds, watershed ponds can be constructed in hilly areas that are not suitable for levee ponds. Watershed ponds are constructed by building earthen dams, or levees, to trap water in a topographic depression within the landscape. Another construction technique uses two- or three-sided ponds that are constructed parallel to hills bordering creeks. Watershed ponds constructed for AAP may sometimes differ from those used as general farm ponds or those used to control large volumes of runoff from agricultural or other types of watersheds. The goal of AAP watershed pond site selection and construction is to have a pond that allows the owner ease of management and harvesting. The USDA's Natural Resources Conservation Service has design criteria for watershed ponds, and local offices often offer site-specific design assistance.

The local topography determines the size and shape of watershed ponds constructed for AAP. On gently sloping or rolling landscapes, the watershed pond is sited and constructed to capture enough water to maintain adequate water levels throughout the year and to minimize the need for water sources other than runoff. On steeper slopes or if available land permits, one or more ponds can be constructed in series to capture larger volumes of runoff during rainy seasons. Another technique for steeply sloped terrain is to divert excess water around the watershed pond. The ponds are constructed with relatively flat bottoms for ease of harvest with seines. The levees are constructed with top widths that are sufficient to drive trucks and other farm equipment on, primarily for feeding and harvesting. Costs for watershed pond construction depend primarily on the amount of soil moved to create levees and smooth pond bottoms.

Depending on the contributing watershed, these ponds could be rather large (in excess of 20 ac). Experience has shown, however, that ponds smaller than 20 ac are easier to manage and harvest than larger ponds. Ponds that are too small (less than about 5 ac for foodfish production) also are not as desirable, especially from a harvesting perspective. Extra labor is required to harvest multiple small ponds to collect enough fish to make centralized processing efficient. The pond size is a function of the watershed, annual and seasonal rainfall, available land, and production goals. Pond depths are kept below 10 ft

[3] Some of the information for this section was adapted from J. Jensen, *Watershed Fish Production Ponds: Site Selection and Construction*, publication no. 102 (Southern Regional Aquaculture Center, Stoneville, Mississippi, 1989).

to facilitate harvesting, enhance aeration and mixing, and meet other pond management needs.

Drains are usually installed in the watershed pond to allow the operator to completely drain the pond when the production strategy requires draining. Watershed ponds are also equipped with overflow pipes to drain smaller volumes of excess water from the ponds during runoff events. The overflows may be piped to adjacent ponds that are constructed and operated in series. At sites in Alabama, for example, up to five watershed ponds were observed in series. A properly designed watershed pond also includes an emergency spillway, which is a low spot along a levee that is grassed and maintained to control runoff. The emergency spillway is sized according to expected runoff volumes, depending on local climatic conditions and the size of the watershed.

The quantity of water available from runoff events for a watershed pond depends on the size of the contributing watershed, frequency and duration of rainfall events, and land use characteristics of the watershed. These factors also greatly influence the quality of water entering the pond during rainfall events. Large watersheds typically collect more water than smaller ones and might present the opportunity for more pollutants to accompany the runoff into the ponds. The frequency and duration of rainfall events have obvious implications on the quantity of water available for the ponds and the amounts that might overflow. (Heavier and more frequent rainfall produces more water.) Watersheds with land uses like roads, houses, and agricultural cropland present different water quality inputs to watershed ponds. For example, roads contribute oil and other petroleum products, metals, and potentially large amounts of suspended solids to watershed ponds.

Management strategies for watershed ponds for AAP depend primarily on the size and type of fish. Watershed ponds are used primarily for the production of catfish, as well as other warmwater and coolwater species such as hybrid striped bass, sunfish, yellow perch, ornamental fish, baitfish, and many sport and game fish. The species and life stage (e.g., fry, fingerling, or food-sized fish) will determine relative densities and many management practices, as shown in the following examples:

> *Catfish food-sized fish.* These fish are often stocked to achieve maximum densities of about 5,000 to 6,000 lb/ac. They can be harvested and understocked with smaller fish to maintain higher biomass and longer periods between draining; complete draining usually occurs once every 7 to 10 yr. Ponds are aerated to maintain dissolved oxygen and water quality. Fish are fed once or twice daily with mechanical feeders.
>
> *Hybrid striped bass food-sized fish.* These fish are often stocked to achieve maximum densities of about 5,000 to 6,000 lb/ac. They must be completely harvested before restocking. (The ponds are drained between harvest and stocking or are treated with a piscicide to remove remaining fish.) Ponds are usually drained annually or biennially, depending on stocking size, and are aerated to maintain dissolved oxygen and water quality. Fish are fed once or twice per day with mechanical feeders.
>
> *Baitfish.* Baitfish are often stocked to achieve a desired number of fish per acre to maintain size requirements at harvest. The overall densities are typically less than

300 to 500 lb/ac. Ponds must be completely harvested before restocking, and they are usually drained annually for maintenance; aeration is used to assist in harvest. Fish are fed minimally to supplement natural food as well as provide nutrients to the pond for natural food production. They are fed by hand or with mechanical feeders. Feeding may also be used to concentrate the fish to facilitate harvesting.

4.2.2 Flow-through Systems[4]

Flow-through systems consist of single- or multiple-pass units with constantly flowing culture water, and they commonly use raceways or tanks (circular or rectangular). Raceways typically are long rectangular tanks constructed of earth, concrete, plastic, or metal. Sizes vary depending on topography and the operational goals of the facility. Some sizes commonly used are 80 ft long, 8 ft wide, and 2.5 ft deep (trout); 100 ft long, 10 ft wide, and 3 ft deep (trout and catfish); or a series of cells 30 ft long, 10 to 20 ft wide, and about 3 ft deep. Many raceways are constructed to reuse the flowing water several times by passing the water through multiple units before discharging it.

Circular or rectangular tanks are also used with constantly flowing water, and they are made from concrete, plastic, or metal. They can be above the ground or placed in the ground, and most use gravity to maintain flows. The primary difference between raceways and tanks is the flow pattern within the containment structure. Raceways tend to have plug flows of water along the length of the raceway. Tanks establish varying flow patterns, depending on the inlet and drain configurations, and the volume of water used. Circular tank systems are operated to enhance solids removal, while raceways allow settling of solids within a portion of the rearing unit.

Flow-through systems are found throughout the United States, wherever a consistent volume of water is available. Most flow-through systems use well, spring, or stream water as a source of production water. The water source is chosen to provide a constant flow with relatively little variation in rate, temperature, or quality.

Flow-through systems are the primary method used to grow salmonid species, such as rainbow trout. These species require high-quality cold water with high levels of dissolved oxygen. Flow-though systems are located where water is abundant, which enables farmers to efficiently produce these types of fish. Some other species cultured using flow-through systems are hybrid striped bass, tilapia, and ornamentals.

Facility size for flow-through systems can vary tremendously. Facilities can range from small earthen or concrete raceway systems producing about 2,000 lb of fish per year to much larger facilities with production levels in the millions of pounds per year.

Most flow-through systems require supplemental oxygen or aeration to maintain sufficient levels of dissolved oxygen in the culture water. The source water might require oxygenation to be suitable for production, or as water is reused in serial units, oxygenation or aeration might be required. In some cases, facilities use mechanical or passive aeration devices to increase the dissolved oxygen concentration of the culture

[4] Information for this section was adapted from J. Avault, 1996a. *Fundamentals of Aquaculture* (AVA Publishing, Baton Rouge, Louisiana).

water. Other facilities might add on-site generated or liquid oxygen to supplement dissolved oxygen levels.

Because many flow-through systems have relatively constant temperatures all year, the fish can be fed year-round. Feeding systems for flow-through systems vary significantly by size and management objectives. Small operators might choose to hand-feed all fish, use demand feeders in different areas of the production facility, or have a mechanical system to deliver feed to the different raceways. Large operators typically use some kind of mechanical feeding system to distribute feed at the desired intervals to meet production goals.

Flowing water in flow-through systems is expected to carry away accumulating waste products, including feces, uneaten feed, and other metabolic wastes. The flowing water and swimming fish help move solids down through the raceway. Raceway systems typically have quiescent zones at the tail ends of the raceways. The quiescent zones allow solids to settle in an area of the raceway that is screened off from the swimming fish. Baffles, or other solids-flushing enhancements, help move solids to the quiescent zones without breaking them into smaller particles. The settled solids are then regularly removed from the quiescent zone by vacuuming or gravity. Flow-through systems with tanks sometimes use self-cleaning or concentrating devices to collect solids and allow them to be efficiently removed from the system. Most facilities store the collected solids in settling basins, convey the solids to a dewatering process, or hold the solids in a storage tank for future disposal.

4.2.3 Recirculating Systems

Recirculating systems are highly intensive culture systems that actively filter and reuse water many times before it is discharged. These systems typically use tanks or raceways to hold the growing animals and have extensive filtration and support equipment to maintain adequate water quality. Recirculating systems use biological filtration equipment to remove ammonia from the production water. Solids removal, oxygenation, temperature control, pH management, carbon dioxide control, and disinfection are other common water treatment processes used in recirculating systems. The size of the recirculating system depends primarily on available capital to fund the project and can be designed to meet the production goals of the operator.

Recirculating systems can be used to grow a number of different species. They can be used anywhere in the country because a relatively small volume of water is needed to produce a unit of product. Thus, the facility can economically temper the water to optimal production temperatures. Recirculating systems grow various species of fish in controlled environments year-round. Species commonly grown in such systems include hybrid striped bass and tilapia.

Feeding regimes in recirculating systems vary significantly from operation to operation. Some operators feed by hand once or twice per day, whereas other operators use automatic feeders to feed the fish at specified intervals throughout the day.

The water treatment processes are designed to minimize water requirements, which leads to small-volume, concentrated waste streams. A typical recirculating facility has one or more discrete waste streams. Solids and backwash water removed from the production system create an effluent that is high in solids, nutrients, and BOD. Most systems add make-up water (about 5% to 10% of the system volume each day) to dilute the production water and to compensate for evaporation and other losses. In addition, some overflow water, which is dilute compared to the solids water, is discharged.

Recirculating system facilities use a variety of methods to treat, hold, or dispose of the solids collected from the production water. Some facilities send the collected solids, and some overflow water, directly to a publicly owned treatment works (POTW) for treatment. Other facilities pretreat in settling ponds or other primary treatment systems to concentrate solids and send a more dilute effluent to the POTW. Still others concentrate solids and then land-apply the solids slurry when practical. The overflow water may be directly discharged, land-applied, or otherwise treated.

4.2.4 Net Pens and Cages

Net pens and cages are suspended or floating holding systems in which some cultured species are grown. These systems may be located along a shore or pier or may be anchored and floating offshore. Net pens and cages rely on tides, currents, and other natural water movement to provide a continual supply of high-quality water to the cultured animals. In most locations, net pens are designed to withstand the high-energy environments of open waters and are anchored to keep them in place during extreme weather events. Strict siting requirements typically restrict the number of units at a given site to ensure sufficient flushing to distribute wastes and prevent degradation of the bottom below and near the net pens.

Net pens use a floating structure to support nets, which are suspended under the structure in the water column. The net pens vary in shape but are typically circular, square, or rectangular on the water surface. Their size also varies, depending on the available surface area and depth. For example, a net pen facility that EPA visited in Maine had 10 adjoining square units, each with a surface area of about 250 ft^2 and a depth of about 40 ft.

A common practice in net pen culture is to use two nets—a containment net on the inside and an outer predator net to keep out predators, such as seals. The predator net also adds protection to minimize the risk of underwater escapement. At the surface, jump nets are used to keep fish from jumping out of the net pen. The jump nets extend several feet above the surface around the perimeter of the net pen. Bird nets are also suspended above the surface of the net pens to prevent bird predation. Cage culture uses floating cages or baskets that are usually much smaller than net pens. The shape of cages varies, and plastic and other corrosion-resistant materials are usually used to construct them.

For cage and net pen culture, the mesh size of the netting used to contain the fish should be large enough to prevent critically reduced water flows when fouling occurs, but small enough to keep the cultured fish inside the structure. Most nets and cages are cleaned mechanically with brushes and power washers. Antifoulants have limited use in the United States. A few have been approved for foodfish production, but those typically show minimal effectiveness.

Net pens and cages are used primarily in the coastal areas of the United States to grow anadromous or near-coastal species of finfish. The species most commonly cultured in net pen and cage operations are anadromous salmonid species like Atlantic salmon *(Salmo salar)*. Other Pacific salmon species, including pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), chinook (*Oncorhynchus tshawytscha*), sockeye (*Oncorhynchus nerka*), and coho (*Oncorhynchus kisutch*), are either grown in net pens for part of their life cycle, prior to release into the open ocean for final growout, or grown to food-size (chinook and coho). Other species, such as steelhead trout (*Oncorhynchus mykiss*), cobia *(Rachycentron canadum),* and redfish (*Sciaenops ocellata),* also can be cultured in net pen operations.

Feeding practices include hand feeding and use of a variety of mechanical feeders. Operators of small cages with a low biomass of fish mostly rely on hand feeding, which necessitates placing the cages near shore with access from land, a dock, or a small boat. Most net pen systems contain a large biomass of fish (e.g., 30,000 fish with a harvest weight of about 8 to 10 lb each) and require the use of mechanical feeders. For net pens that are single structures without supporting walkways, barges and boats with feed blowers are used to take feed to the net pens and dispense feed, usually once or twice a day. Bad weather can impede this method of feeding. Other facilities may use a stationary blower to deliver feed to each net pen in a group of pens. To control overfeeding, many facilities use underwater cameras to monitor feed consumption.

Most net pens are regularly inspected by divers. The divers look for holes in the nets, dead fish, and fouling problems. State regulatory programs require benthic monitoring at many net pen sites to ensure that degradation is not occurring under or around the net pens.

4.2.5 Floating and Bottom Culture Systems[5]

The production of bivalves in the United States involves several different methods, which are selected based on variables such as species, location, and legal or political issues. The commercial growout of bivalves always relies on naturally occurring foods that are present in the water in which the bivalves are placed. The key to successful floating and bottom culture is sufficient tides and currents to move water containing natural food to the shellfish. The water movement must also move wastes away from the growing shellfish and minimize the accumulation of sediment. Harvests can be made with divers, lifting gear, or conventional shellfishing techniques. The basic growout techniques use the intertidal areas above mean low water (but within the tidal reach) and the subtidal areas (areas always submerged). Those techniques can be further subdivided into techniques that use the bottom and those that use the water column. Some species are better suited for off-bottom culture (e.g., mussels); other species (e.g., clams and oysters) may be grown in either bottom or off-bottom growout systems. The specific locations of a growing area and that area's tidal characteristics (e.g., whether it is intertidal or subtidal) dictate the choice of intertidal versus subtidal growout. Other factors, such as legal restrictions, social pressure, waterway use, and aesthetics, might dictate the culture method.

[5] The information for this section was adapted from J. Kraeuter, et al., 2000, Preliminary Response to EPA's Aquaculture Industry Regulatory Data Development Needs, Molluscan Shellfish Technical Subgroup.

One popular bottom culture technique places the shellfish directly on the bottom in beds. Clams tend to dig into the bottom substrate, while oysters and mussels remain on top of the substrate. When predation is a problem, the shellfish are placed in mesh bags or covered with mesh to keep the predators away from the growing crop. Bottom culture techniques require a relatively firm bottom to keep the shellfish from sinking too deep into the substrate. Bottom culture does not work when excessive sediment settles over the shellfish beds and smothers the crop. Shellfish can also be placed in trays, nets, or racks positioned directly on the bottom.

Off-bottom culture techniques include suspending shellfish from longlines on strings or racks. Longlines can also be used to suspend the shellfish in bags or racks. Floats are sometimes used to suspend strings, bags, or trays of shellfish in the water column. Racks of strings are a popular off-bottom method of growing mussels.

4.2.6 Other Systems: Alligator Farming

The only species of alligator commercially produced in the United States is the American alligator *(Alligator mississipiensis)*. Alligator production, which takes place primarily in Louisiana and Florida, is a relatively new business that is still undergoing many changes.

Alligator production facilities usually consist of corrugated metal buildings constructed on top of concrete slabs with walls that form a tank. The buildings are insulated to reduce heating costs during the winter. To maintain the desired temperature, heated water is circulated through a piping network encased in the concrete floor. The drainage structures for alligator production facilities differ greatly from facility to facility, but most have a single drain for each alligator pen in the production area. These pen drains usually combine to form a main drain, which conveys wastewater to the wastewater treatment operations for the facility.

Alligator feeding regimes have changed significantly since alligator farming first began. Currently, most alligators are fed a manufactured diet consisting of pelleted feed with the same feedstocks used for finfish feeds.

Cleanliness of the growout areas is important to the production of high-quality skins for eventual sale. Most alligator pens are cleaned every other day using a high-pressure hot-water spray, sometimes combined with small amounts of bleach to reduce the risk of bacterial infection. Water drained from the growout areas is usually discharged to a singular treatment lagoon or a series of lagoons before it is land applied for its fertilizer value.

4.3 PRODUCTION DESCRIPTION BY SPECIES

4.3.1 Catfish

Representing nearly half of the total AAP in the United States for all species, production of channel catfish (*Ictalurus punctatus*) is the largest AAP enterprise in the country. In 2000, more than 656 million pounds of channel catfish were produced commercially. In 2001, sales increased to over 670 million pounds (USDA, 2002). Production is concentrated in the southeastern United States: Mississippi, Alabama, Arkansas, and Louisiana account for 97% of the total domestic catfish production (USDA, 2002).

Catfish growers in 13 select states had sales of $443 million in 2001, down 12% from the previous year (USDA, 2002). Prices per pound dropped from $0.75 in 2000 to $0.65 in 2001.

The original range of channel catfish extended from northern Mexico through the states bordering the Gulf of Mexico and up the Mississippi River and its tributaries (Tucker, 2000). Today, the channel catfish can be found throughout the world as a sport fish and an AAP product. A native North American freshwater fish, the channel catfish is a bottom dweller with a preference for a substrate of sand and gravel. Its natural habitat is sluggish to moderately swift rivers and streams; however, channel catfish also thrive in ponds and lakes.

Between 1955 and 1965 most of the growth in commercial catfish culture occurred in southeast Arkansas. Farmers discovered that raising fish could be a profitable alternative to growing traditional crops like rice and cotton. By 1975, the industry began to expand quickly, particularly in Mississippi, where profits from traditional agriculture were in decline. Aquaculture offered farmers an opportunity to diversify their crop production and use land that did not successfully support row crops. Cooperation among farmers helped create the infrastructure needed to support catfish production, including the development of large feed mills and fish processing plants. In 1968, the creation of a national grower's association, the Catfish Farmers of America, also enhanced the growth of the industry. In 1986 the Catfish Institute, an association of catfish farmers, processors, and feed manufacturers, launched a national marketing campaign, further strengthening the industry.

Today most catfish farms are family farms or partnerships. According to the USDA, about 88% of catfish farms are small businesses with annual sales of less than $750,000 (USDA, 2000). Of the 1,370 catfish farms in the United States, 38% reported annual revenues of less than $25,000. Catfish production plays a significant role in the southeastern United States, a region that continues to be one of the more economically challenged regions in the country.

4.3.1.1 Production Systems

Facilities and culture practices vary within the southeast region. Many studies on catfish farming have focused on practices in northwest Mississippi (Tucker et al., 1996; Tucker and van der Ploeg, 1993) and west-central and central Alabama (Boyd et al., 2000; Schwartz and Boyd, 1994b). There are fewer studies on catfish farming practices in Louisiana and Arkansas, the other two leading producers of commercial catfish, or on practices in other states with catfish farms.

In the southeastern United States, the two major catfish-producing areas are (1) the Mississippi River Alluvial Valley, which includes northwest Mississippi, southeast Arkansas, and northeast Louisiana, and (2) west-central Alabama and east-central Mississippi (JSA, 2000a). Because of the flat topography and an available groundwater source, many catfish farms in the Mississippi River Alluvial Valley use levee (embankment) ponds. Levee ponds are built by removing dirt from the area that will become the pond bottom and using that dirt to build levees around the pond perimeter. In west-central Alabama and east-central Mississippi, some catfish farms use watershed ponds. Watershed ponds take advantage of hills and sloping terrain to build a pond by damming an existing drainage area to capture rainwater and runoff from the watershed. Many watershed ponds also require an additional source of water to supplement rainwater and runoff.

Overall, by operation size in acres, about 90% of all commercial catfish ponds in production in the United States are levee ponds; the remaining 10% are watershed ponds (USDA, 1997).

Levee Ponds

Ponds in northwest Mississippi are predominantly levee ponds. Most ponds are rectangular with about a 3:1 to 5:1 ratio of length to width with an average pond size of between 8 and 15 ac of water surface. For ease of harvest, most pond depths range from 3 to 5 ft. The height of the levee is 1 to 2 ft above normal water stage (freeboard and storage) (JSA, 2000a).

Watershed Ponds

In west-central Alabama and east-central Mississippi, commercial catfish farms use both levee and watershed ponds. The average size of ponds in this region is 10 to 12 acres. The average maximum depths are 7 ft at the pipe and 3 ft on the shallow end. The height of the levee for a watershed pond is around 3 ft above normal water stage. Watershed ponds can expect more input from rainwater and runoff because a larger natural watershed area drains into the pond. A levee pond has a smaller "watershed" contained within the slopes of the levee.

About 75% of the commercial catfish ponds in west-central Alabama are watershed ponds. The remaining 25% of the ponds in this region are levee ponds, filled with water pumped mainly from groundwater wells (JSA, 2000a). About half of the ponds in east-central Mississippi are watershed ponds, and the other half are levee ponds or hybrid watershed-levee ponds that primarily use water pumped from nearby streams or other surface water supplies rather than from groundwater supplies (JSA, 2000a).

4.3.1.2 Culture Practices

Catfish AAP in ponds involves four phases: (1) broodfish production, (2) hatchery production, (3) fry nursery production, and (4) growout production (JSA, 2000a). Broodfish are held in ponds and allowed to randomly mate each spring. Spawning occurs when the water temperature rises above 70 °F. Fertilized eggs are then taken to a hatchery, where they hatch under controlled conditions. The fry are raised in the hatchery for 5 to 15 d and are then transferred to a nursery pond, where they are fed a manufactured feed throughout the summer and fall. Fingerlings weighing 0.7 to 1.4 oz are seined from the nursery pond and transferred to the foodfish growout ponds in winter or spring, where they are fed a manufactured feed until they reach the size desired for processing, usually 1 to 2 lb. In the southeastern United States, 18 to 30 mo (two or three growing seasons) are required to produce a food-size channel catfish from an egg (JSA, 2000a). Within the industry, some farmers specialize in producing fingerlings. The fingerlings are then sold to farmers who specialize in growing food-size fish. Many farmers combine all aspects of production by having broodfish ponds, a hatchery, fry nursery ponds, and growout ponds. In the catfish industry, fish are usually harvested from growout ponds with long seine nets pulled by tractor-powered reels. The fish are transferred to live-haul trucks in a basket connected to a crane. Using different mesh sizes, the seines are designed to capture market-sized fish and allow smaller fish to remain in the pond. The captured fish are then transported to processing plants or directly to market.

Broodfish ponds represent about 2% of the total pond area devoted to catfish production. Although some farmers harvest and drain broodfish ponds every fall to replace poor breeders and adjust the sex ratios, most broodfish ponds in northwest Mississippi are drained only every 1 to 5 yr (Tucker, 1996). Instead of draining the pond every year, broodfish are inspected by seining the pond. In Alabama very few commercial hatcheries remain in operation (Boyd et al., 2000). Most fingerlings stocked in Alabama ponds are imported from Mississippi.

After a short stay in the hatchery, the fry are moved to a nursery pond for further growth. Nursery ponds are stocked with approximately 100,000 to 300,000 fry/ac. Because recently transferred fry are weak swimmers, farmers prepare a natural plant food source for fry that are too weak to swim to the areas where feed is offered (Tucker, 2000). After a month or so, as the fry approach 2 in. in length, they are referred to as fingerlings. Fingerlings ranging in age from 5 to 9 mo and weighing 0.7 to 1.4 oz are harvested from the nursery ponds and placed in growout ponds. The nursery ponds are harvested by seining each pond several times over 1 to 3 mo. The mesh size of the seine grades the fish by size, releasing smaller fingerlings back into the nursery pond for further development.

Nursery ponds are usually drained each year to remove all fish from the pond. Fingerlings are removed from the pond to prevent cannibalism of fry in the next cycle of fingerling production (Tucker, 2000). Nursery ponds represent approximately 10% of the total pond area in commercial production. Because these ponds are drained each year between crops, water use is higher in nursery ponds than in broodfish or foodfish growout ponds (Tucker and Hargreaves, 1998).

Broodfish and nursery pond practices remain fairly constant throughout the industry, but foodfish culture practices often vary among different farms based on production goals and the economics of different production strategies. There are two fundamental production variables in foodfish growout, fish stocking density and cropping system (Tucker and Robinson, 1990). Stocking densities in growout ponds range from 4,000 to more than 12,000 fish/ac and average about 6,000 fish/ac. The cropping system refers to the stocking-harvest-restocking schedule. The two cropping systems in commercial catfish production are clean harvest and understocking (or multiple-batch). In the clean harvest system, farmers keep only one year-class of fish in the pond at one time. Fingerlings are stocked and grown to the desired harvest size (1 to 2 lb/fish). Faster-growing fish are selectively removed by seining the pond in two to four separate harvests over several months until all of the fish are removed. After the harvest, the pond is often restocked without draining in order to conserve water and to reduce time lost between crops (Tucker, 2000).

The understocking or multiple-batch system has more than one year-class of fish (with three or four distinct size-classes of fish) after the first year of production. Multiple-batch harvesting is the predominant production type, accounting for 89.2% of foodfish harvest (USDA, 1997). At first the pond is stocked with a single year-class of fingerlings. Faster-growing fish are selectively harvested using large-mesh seines, and fingerlings are added to replace the harvested fish. Most commercial catfish ponds in Alabama use multiple-batch systems and harvest with seines (Boyd et al., 2000). This process of selective harvest and understocking (adding fingerlings) continues for years without draining the pond. After several cycles, the pond contains several year-classes of fish with a range of sizes from recently stocked fingerlings to fish that might be several years old.

The clean harvest system produces fish more uniform in size than fish from understocked ponds, and processors prefer uniform sizes (Tucker and Robinson, 1990). Inventory records are also easier to keep with the clean harvest system because populations are reset at zero after each crop cycle. With the clean harvest system, feed conversion efficiencies are better because larger fish, which convert feed to flesh less efficiently, are not carried over into the next production cycle. The advantage of the understocking system is that more ponds will have market-size fish at any one time than with clean harvest crops. This is important because it provides a farmer with other harvest options if a pond is temporarily unacceptable for processing because of factors like algae-related off-flavors or ongoing losses due to infectious disease.

Water use practices have shifted in the catfish industry in recent years. Today farmers use water more conservatively. Before 1985, many catfish ponds in northwest Mississippi were regularly refilled with pumped water (Tucker and Hargreaves, 1998). Farmers believed that “flushing” the pond improved productivity. Research by McGee and Boyd (1983), however, showed that “flushing” was generally not beneficial. Today almost all catfish ponds in northwest Mississippi are managed as “static” systems with very little water exchange except from heavy rain creating overflow. In another study in Alabama (Seok et al., 1995), in a period of 3 yr, three ponds were harvested annually by draining and three were harvested without draining. There were no differences in net production, average fish size at harvest, or feed conversion rates; however, in the undrained ponds, concentrations of chlorophyll *a* and total ammonia nitrogen were higher. This study has reinforced the practice of harvesting without draining, a management practice that is now common throughout the catfish industry.

Daily management practices for both crop systems are similar. Today, foodfish ponds are usually drained only when a levee needs to be repaired or when there is a need to adjust the inventory by completely removing all fish. Table 4.3-1 shows that most commercial ponds remain in production for 3 to 10 yr between renovations before being drained, and the average time between pond drainings is over 6 yr (USDA, 1997). On average, producers drained ponds less often (every 6.4 yr) at operations where 90% or more of the ponds were levee ponds than at operations with a smaller percentage of levee ponds (every 4.7 yr). Smaller operations (measured by acreage) drained ponds more often regardless of predominant pond type. During renovation the pond bottom is dried and the dried clay is broken by disking the bottom. Dried material is scraped from the bottom and used to rebuild the levee and restore the proper pond slope.

Table 4.3-1. Number of Years Between Drainings By Pond Type and Operation Size

Operation Size (Acres)	*Pond Type*[a]					
	Levee Ponds	*Standard Error*	*Watershed/ Mixture Ponds*	*Standard Error*	*All*	*Standard Error*
1-19	3.1	(± 0.4)	2.4	(± 0.5)	2.9	(± 0.3)
20-49	5.9	(± 0.5)	2.6	(± 0.8)	5.1	(± 0.5)
50-149	6.1	(± 0.3)	8.4	(± 1.7)	6.5	(± 0.4)
150 or more	8.7	(± 0.4)	9.7	(± 0.7)	8.8	(± 0.4)
All	6.4	(± 0.2)	4.7	(± 0.8)	6.1	(± 0.2)

[a]Pond type for the operation was classified levee if at least 10% of the operation's ponds were reported as levee ponds. Otherwise, the pond type was classified as "Watershed/Mixture."
Source: USDA, 1997.

Feed Management

Feed allowances in growout ponds average between 75 to 125 lb/ac/d during late spring and early summer (Tucker, 2000). Feeding activity declines as water temperatures drop in late fall, with feeding rates declining to less than 25 lb/ac/d during midwinter; however, feeding allowances may be higher during unusually mild winters. A report from the USDA's Animal and Plant Health Inspection Service (APHIS) found that 87.5% of operations with fish on hand during winter fed their foodfish during winter, with 62.8% feeding 3 or more days per month (USDA, 1997). Operators identified water temperature and levee condition as being very important criteria in determining winter feeding schedules.

The cost of feed depends on its quality and contents. The conversion of feed protein to fish protein is important because protein is the most expensive feed ingredient, based on the amount of protein in the feed and the cost of the protein used. In most catfish feed, a portion of the protein comes from fish meal and sometimes other animal sources. In recent years, the industry has improved upon earlier catfish feeds. Modern feeds contain less crude protein and a much smaller percentage of animal protein (Boyd and Tucker, 1995).

The feed conversion ratio (FCR) is a measure of the feeding efficiency. It is calculated as the ratio of the weight of feed applied to the weight of the fish produced:

$$\text{FCR} = \frac{\text{Dry weight of feed applied}}{\text{Wet weight of fish gained}}$$

Commercial catfish farms in Mississippi typically achieve a feed conversion ratio of 2.04 to 2.40 (Boyd and Tucker, 1995). Much lower feed conversion ratios (in the 1.3 to 1.5 range) can be reached in research ponds under conditions where fish are less crowded, have less wasted food, and live in water with better aeration than is found on most commercial farms (Boyd and Tucker, 1995). The feed conversion ratio is an important tool that operators use for measuring the efficiency of the system. If stocking rates are too low, efficient feeding becomes more difficult (fish are too spread out), and thus increasing the stocking density would improve FCR. When stocking and feeding rates are increased to the point where water quality is negatively impacted, however, FCR increases (poorer efficiency). As the growing season progresses, the fish grow and require more feed. As feeding rates increase, water quality tends to deteriorate as a result of excessive phytoplankton (microscopic algae), increased oxygen demand, and high concentrations of nutrients, including total ammonia nitrogen. In ponds that use the multiple-batch system, removing marketable fish and adding new fingerlings, the feeding rate might remain more constant because the number of pounds of foodfish per acre levels out as large fish are removed and small fish are added.

Health Management

High fish densities and stressful environmental conditions can lead to the outbreak and rapid spread of infectious diseases in channel catfish ponds. Bacterial diseases account for most of the losses of fingerlings in nursery ponds, whereas foodfish in growout ponds are most often affected by proliferative gill disease (PGDs, caused by the myxosporean parasite) and "winter-kill syndrome," a disease associated with external fungal infections (Tucker, 2000). PGD occurs most often in spring and autumn when temperatures are between 60 and 68 °F. There is no treatment for the disease, but farmers can reduce losses by maintaining high dissolved oxygen levels during an outbreak. "Winter-kill syndrome" is common when temperatures fall below 60 °F. Mortality rates from this fungal infection can be high, and the conditions that contribute to its outbreak are not well understood. There is no cost-effective treatment available for fungal infections in large commercial ponds.

The channel catfish virus (CCV) affects young catfish and can lead to large losses in hatcheries or nursery ponds. The virus causes channel catfish virus disease (CCVD), and fish less than 1 mo old are most susceptible. There is no cure for CCVD, but losses can be reduced by controlling water temperature in hatcheries and reducing stress in fry or fingerling populations by maintaining relatively low stocking densities, avoiding stressful handling, and preventing adverse environmental conditions (Plumb, 1994a; Winton, 2001).

Three bacterial diseases are significant to channel catfish AAP because they can cause large losses: enteric septicemia of catfish, columnaris disease, and motile aeromonad septicemia.

Enteric septicemia in catfish (ESC) is one of the leading bacterial diseases in commercial catfish production. This disease costs the industry millions of dollars annually in fish mortalities and expenditures for preventive measures and therapeutic treatments (Plumb, 1994b; Winton, 2001). Only two Food and Drug Administration (FDA)-approved drugs, oxytetracycline (Terramycin) and sulfadimethoxine-ormetroprim (Romet), are effective against ESC. Today farmers rely more on vaccination and management practices to reduce stress to prevent ESC rather than drug treatments.

Two other bacterial diseases are often encountered in channel catfish production: motile aeromonas septicemia (MAS), a ubiquitous disease of many freshwater fish species, and columnaris, caused by *Flexibacter columnaris.* MAS is typically caused by one of several gram-negative, motile bacteria that are members of the genus *Aeromonas*, such as *A. hydrophila*, *A. sobria*, and *A. cariae*. Occasionally, various species of *Pseudomonas*, especially *Pseudomonad fluorescen*s, can cause a form of disease that is indistinguishable from MAS (Winton, 2001).

Most columnaris infections in channel catfish are mixed infections with other bacteria, especially ESC and MAS. Initial columnaris infections are usually the result of mechanical or physiological injuries or environmental stress. MAS is also a stress-mediated disease. Treatment with a 1% to 3% salt solution or 2 to 4 mg/L of potassium permanganate reduces the incidence of post-handling infections.

Infectious disease is a significant problem in catfish production that is primarily controlled by preventing the poor water quality conditions that lead to outbreaks. Pond culture of catfish prohibits the use of most drugs and chemicals for treatment because of the high cost of treating the large water volume. Sick fish tend not to eat, so the few FDA-approved medicated feeds are limited in their effectiveness.

Some algae and bacteria that grow in catfish ponds produce odorous organic compounds that can give the fish undesirable off-flavors. Synthesized by blue-green algae, geosmin, an earthy-smelling compound, and 2-methylisoborneol, which has a musty smell, are the two most common causes of off-flavors in pond-raised catfish (Tucker, 2000). To prevent off-flavored fish from reaching the market, fish are taste-tested before harvest. In Alabama it is a common practice to treat ponds with copper sulfate to control blue-green algae and off-flavor in ponds. Studies show that copper precipitates rapidly in ponds and is unlikely to be a concern in effluents (Boyd et al., 2000).

4.3.1.3 Water Quality Management and Effluent Treatment Practices

Water Quality in the Production System

In catfish ponds, the most important constituents of potential effluents are nitrogen, phosphorus, organic matter, and settleable solids (JSA, 2000a). These materials are a direct or indirect product of feeds added to the ponds to promote rapid fish growth. Farmers need relatively high stocking and feeding rates to reach profitable levels of production. Although catfish are able to convert more feed into flesh than warm-blooded animals, nutrient use is not as efficient. Less than 30% of the nitrogen and phosphorus added to the pond in feed is recovered in the harvested fish (JSA, 2000a). The remainder of the nutrient load stays in the pond system as fish waste. Inorganic nutrients in fish waste stimulate the growth of phytoplankton, which in turn stimulate the production of more organic matter through photosynthesis. For both watershed and levee ponds, nitrogen and phosphorus compounds and organic matter are present in the pond water throughout the growout period and represent potential pollutants if discharged.

Fish wastes contain nitrogen, phosphorus, and other nutrients required for plant growth. The input of these nutrients, particularly in the summer growing season, stimulates the growth of plant communities in catfish ponds. Although some ponds may develop rooted aquatic plants, the most common plant form is phytoplankton (Tucker, 1996). Phytoplankton are producers as well as users of oxygen. They also assimilate ammonia as a nitrogen source of growth (Tucker, 1996). Phytoplankton can be beneficial to the catfish pond system; however, a pond with high levels of phytoplankton biomass might use more oxygen than it produces, resulting in a community deficit of dissolved oxygen.

Catfish need sustained levels of dissolved oxygen. Ideally, minimum dissolved oxygen concentrations need to be between 4 and 5 mg/L to maintain the health of the fish (Tucker, 1996). Aerators are one of the most common control technologies used in the catfish industry to improve water quality. Mechanical aerators improve the quality of the water in the pond by continually mixing the water and preventing thermal stratification. Aeration also adds dissolved oxygen to the system. By enhancing dissolved oxygen concentrations, aeration increases the capacity of ponds to assimilate organic matter through aerobic processes. Higher dissolved oxygen concentrations also increase the nitrification rate of ammonia to nitrate, which is then lost from the pond through denitrification. In addition, aeration and water circulation influence rates of phosphorus loss from the system. The interface between water and sediment in aerated ponds appears to be sufficiently oxidized to enhance rates of inorganic phosphorus removal from pond water and reduces the availability of phosphorus for phytoplankton (JSA, 2000a). Furthermore, circulation can also improve water quality by increasing nutrient uptake by phytoplankton. Water circulation increases the aggregate exposure of phytoplankton cells to light, resulting in an increase in phytoplankton growth rates, which in turn increases the nutrient uptake.

Over time natural processes in the pond lower the concentrations of nitrogen, phosphorus, and organic material. If water is retained in catfish ponds over a period of time, biological, chemical, and physical processes remove some of the waste generated by fish. Some of the organic matter from phytoplankton production and fish waste is oxidized in the natural process of microbial decomposition (JSA, 2000a). Total nitrogen levels in catfish pond waters are lowered as nitrogen is lost from the water column as organic matter with nitrogen particulates is decomposed on the bottom of the pond. Nitrogen is also lost from the water as a gas through denitrification and volatilization. Finally, total phosphorus concentrations in the water are lowered as phosphorus is lost to the pond bottom soils as particulate organic phosphorus and precipitates of calcium phosphates.

Effluent Characteristics

The major components of concern from catfish pond effluents are solids, organic matter, phosphorus, and nitrogen. Based on these components, the major potential impact on receiving waters is the possibility of eutrophication. The impact on the receiving waters will depend on the volume and concentration of substances in the effluent in relation to the flow rate of the receiving body of water and the timing of the effluent discharge (JSA, 2000a).

Watershed ponds and levee ponds, as well as the different production practices used by different facilities, influence water use practices and water quality in the ponds. In turn, water quantity and quality affect the discharge volume and the characteristics of the water discharged, or effluent, from catfish production. Effluent from a pond may be discharged intentionally. For example, a pond might be periodically drained for harvest or maintenance. Ponds might also discharge water though unplanned events, such as overflow due to excessive rainwater and runoff.

General characteristics of overflow from catfish ponds in northwest Mississippi are described in a study (Table 4.3-2) that examines long-term changes in the quality of effluents from typical commercial catfish ponds (Tucker et al., 1996). Water samples were taken from 20 ponds in Washington County in northwest Mississippi over a 2-yr period beginning in summer 1991. These ponds represented typical culture practices of ponds used to produce catfish in the area. Samples were taken in August (summer), November (autumn), February (winter), and May (spring). Samples were collected from the top 12 inches of the surface of the pond and the bottom 12 inches of the pond at a site adjacent to the discharge pipe. Samples were taken at two different depths because water can be discharged from ponds at either the surface or the bottom, depending on the type of discharge pipe. Samples were analyzed for biochemical oxygen demand (BOD), chemical oxygen demand, total ammonia, total nitrogen, nitrite, nitrate, total phosphorus, soluble reactive phosphorus, suspended solids, and settleable solids.

Table 4.3-2. Means and Ranges of Potential Effluents Parameters from 20 Commercial Channel Catfish Ponds in Northwest Mississippi from Summer 1991 Through Spring 1993

Season	*Settleable Solids (mL/L)*	*Suspended Solids (mg/L)*	*Total Nitrogen (mg N/L)*	*Total Ammonia (mg N/L)*	*Total Phosphorus (mg P/L)*	*Biochemical Oxygen Demand (mg O_2/L)*
Summer 1991	0.20 (0–0.90)	127 (40–225)	6.1 (2.1–14.1)	1.22 (0.01–3.19)	0.54 (0.23–1.24)	26.1 (14.6–41.2)
Autumn	0.02 (0–0.25)	80 (20–225)	6.1 (2.9–10.8)	2.63 (0.05–6.35)	0.26 (0.14–0.58)	9.7 (1.9–29.7)
Winter 1992	0.06 (0–0.70)	109 (51–194)	5.1 (2.1–8.8)	0.86 (0.04–3.85)	0.34 (0.13–0.62)	13.7 (5.7–20.3)
Spring	0.11 (0–1.35)	123 (72–204)	4.5 (1.8–6.7)	1.06 (0.04–3.04)	0.31 (0.15–0.56)	14.8 (8.2–27.1)
Summer	0.09 (0–0.58)	117 (47–175)	7.0 (2.6–10.9)	0.71 (0.03–2.02)	0.51 (0.26–0.87)	21.2 (10.5–36.4)
Autumn	0.02 (0–0.15)	93 (41–175)	6.9 (3.8–10.4)	2.76 (0.07–8.10)	0.35 (0.15–1.03)	12.3 (5.4–34.0)
Winter 1993	0.01 (0–0.03)	93 (39–165)	5.5 (0.6–8.8)	1.48 (0.02–5.14)	0.34 (0.14–0.62)	11.9 (4.8–22.9)
Spring	0.12 (0–0.70)	135 (46–289)	5.2 (1.5–7.9)	2.21 (0.03–4.44)	0.37 (0.24–0.58)	14.9 (8.5–25.5)

Source: Tucker et al., 1996.
Note: Ranges are in parentheses.

Pond effluents varied from pond to pond, season to season. Typically the quality of potential effluents was poorest in the summer, with high concentrations of solids, organic matter, total phosphorus, and total nitrogen. This same trend was confirmed by other studies of catfish pond water quality (e.g., Tucker and van der Ploeg, 1993).

Long-term changes in quality of effluents in typical commercial catfish ponds in central and west-central Alabama are described in a study (Table 4.3-3) by Schwartz and Boyd (1994b). They collected water samples during February, May, August, and November of 1991 and 1992 from 25 commercial catfish ponds using the same sampling method used in the study described above. Samples were analyzed for 5-day biochemical oxygen demand, total ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, soluble reactive phosphorus, nitrite, nitrate, total ammonia, suspended solids, volatile solids, and settleable solids.

Table 4.3-3. Means and Ranges of Potential Effluent Parameters from 25 Commercial Channel Catfish Ponds in Central and West-Central Alabama from Winter 1991 Through Autumn 1992

Season	*Settleable Solids (mL/L)*	*Suspended Solids (mg/L)*	*Kjeldahl Nitrogen (mg N/L)*	*Total Ammonia (mg N/L)*	*Total Phosphorus (mg P/L)*	*Biochemical Oxygen Demand (mg O_2/L)*
Winter 1991	0.06 (0–0.33)	81 (22–202)	3.7 (0.9–9.2)	0.7 (0.07–2.47)	0.25 (0.04–0.57)	9.0 (1.2–21.9)
Spring	0.05 (0–0.40)	52 (5–134)	4.4 (1.8–10.6)	1.07 (0.02–3.45)	0.21 (0.07–0.37)	6.5 (2.4–21.4)
Summer	0.19 (0–1.80)	96 (14–240)	5.0 (1.7–11.3)	0.85 (0.05–4.71)	0.36 (0.12–0.75)	10.7 (4.3–20.3)
Autumn	0.03 (0–0.54)	103 (18–232)	6.1 (2.2–11.5)	1.86 (0.10–8.07)	0.46 (0.12–1.85)	18.1 (6.1–35.6)
Winter 1992	0.01 (0–0.10)	29 (1–100)	1.9 (0.6–3.7)	0.27 (0.03–1.08)	0.09 (0–0.31)	9.2 (5.5–17.5)
Summer	0.15 (0–0.28)	102 (10–308)	3.9 (1.6–8.4)	1.89 (0.06–3.30)	0.19 (0–0.47)	8.0 (1.4–15.9)
Autumn	0.03 (0–0.25)	73 (14–337)	6.0 (2.2–14.0)	1.91 (0.09–5.26)	0.27 (0.06–0.83)	7.6 (1.2–23.4)

Source: Schwartz and Boyd, 1994b.
Note: Ranges are in parentheses.

Settleable solid concentrations were highest during the summer and were generally greater in the surface waters. Phytoplankton were the major source of suspended solids in the samples. The other effluent parameters (e.g., suspended solids, TKN, BOD, total ammonia, and total phosphorus) generally cycle throughout the year. These effluent parameters are usually lower in the spring, increase through the summer, peak in the fall, and then decrease in the winter.

Overall, concentrations of settleable solids and suspended solids were similar in Alabama and Mississippi catfish ponds. Concentrations of Kjeldahl nitrogen in Alabama ponds and total nitrogen in Mississippi ponds are not directly comparable because of a difference in analytical methods; however, if nitrogen compounds not measured in the Kjeldahl analysis are accounted for, values for total nitrogen are probably similar in both studies. Concentrations for total phosphorus and BOD are somewhat higher in ponds in Mississippi. This is probably a result of the higher fish stocking and feeding rates commonly used in Mississippi, which might lead to higher standing crops of phytoplankton (Tucker et al., 1996).

Schwartz and Boyd (1994a) also conducted a study to describe the quality of effluents drained for harvest. This study was conducted in three watershed ponds at the Alabama Agricultural Experiment Station near Auburn. Ponds were stocked with 4,000 fingerling channel catfish per acre and were fed a pelleted commercial feed during the growing season and intermittently during the winter. This study showed that concentrations of TKN, BOD, and settleable solids were fairly constant throughout the draining phase. As the pond level was lowered and the seining phase began, these variables increased in concentration. Total ammonia nitrogen, soluble reactive phosphorus, and total phosphorus steadily increased during the draining phase and then sharply increased during the seining phase. Increases in phosphorus were likely a result of sediments being stirred up. The rise in total ammonia-nitrogen concentrations was likely a result of metabolic wastes, becoming more concentrated in a decreasing volume of water.

Draining a pond for harvest concentrates fish into a relatively small volume of water, causing sediments to be stirred up by the fish and the nets. Water discharged during harvest contains solids and other substances from the disturbed sediments and is, therefore, different from typical pond water (JSA, 2000a). The findings from this study suggest that the best way to minimize impacts from effluents from ponds drained for harvest is to harvest ponds as quickly as possible, and either to not discharge the water during the seining process or to discharge this highly contaminated water into a settling basin or retention pond (JSA, 2000a). As noted in the report prepared by the Technical Subgroup for Catfish Production in Ponds for the Joint Subcommittee on Aquaculture, most ponds are not drained for harvest (JSA, 2000a). Draining ponds for harvest is practiced mostly in watershed ponds that have deep areas near the dam that prevent harvest by seining. Watershed ponds are common in areas such as west-central Alabama and east-central Mississippi, but overall they constitute a small proportion of ponds used in catfish farming.

Current Industry Effluent Treatment Practices

In addition to natural processes in ponds that help improve water quality by reducing levels of organic material and concentrations of nitrogen and phosphorus, catfish farmers also play a role in improving in-pond water quality through best management practices (BMPs).

Effluent volume from levee ponds is lowered by two common management practices in the catfish industry. The practices, which include keeping the pond water level below the level of the drain and not draining water between crops, significantly reduce the volume of water discharged (JSA, 2000a).

As demonstrated in a study by Tucker et al. (1996), reuse of water for multiple crops results in significant savings in water use and also reduces overall effluent volume. This study modeled the effect of water reuse on mass discharge of nutrients and organic matter for levee ponds operated at three intervals (1, 3, and 5 yr) between total pond drainings and managed with and without storage potential. Harvesting fish without draining the ponds between crops substantially reduced the average volume of water discharged each year, and the reduction was greatest when ponds were also managed to maintain storage potential. For ponds not managed to maintain surplus water storage, the model indicated that using the ponds for 5 yr before draining reduced the annual average waste discharge by approximately 45% compared to annually drained ponds. When ponds were managed for surplus water storage, discharge of nutrients and organic matter was reduced relative to annually drained ponds by more than 60% when ponds were used for 5 yr between drainings. Currently, the average time between production pond drainings is more than 6 years.

The following is a summary of common practices in the catfish industry and the ways in which they affect effluent quality.

Draining practices. Draining practices are a function of harvest practices. Water is most commonly drained from a pond to facilitate harvests, prevent predation in fingerling ponds, or maintain pond banks and bottoms. Catfish production is characterized by infrequent drainings. Although nursery ponds are drained annually, growout ponds are drained once every 5 to 10 (or more) yr. When the water is used for several years between draining events, effluent volumes are significantly reduced.

Harvest practices. Fish raised in ponds are typically harvested using seines that can be stretched across the entire pond. Catfish are usually harvested with seine nets without draining the ponds. Some watershed ponds require partial draining before harvest to capture fish in the deeper end of the pond adjacent to the dam (Tucker et al., 2002). Ponds harvested without draining have reduced effluent volumes. Draining and seining also affect effluent pollutant loads.

Feed management. Feed management is one of the most important practices that can influence water quality in the pond system. By managing feed, farmers manage the amount of nutrients in the form of fish waste and uneaten feed that are added to the pond system. Water quality in catfish ponds is directly related to the amount of feed added to the ponds. Uneaten feed contributes only to lowering of water quality, not to fish growth.

Water quality management. Catfish need sustained levels of dissolved oxygen at 4.0 mg/L or above. Most catfish farmers use paddlewheel aerators to supply sufficient aeration for production. Mechanical aeration is required to maintain adequate water quality and oxygen levels in the ponds. Mechanical aerators improve the quality of the water in the pond by continually mixing the water and preventing thermal stratification. Aeration also adds dissolved oxygen to the system. By enhancing dissolved oxygen concentrations, aeration increases the capacity of ponds to naturally assimilate organic matter through aerobic processes.

Overflow management. Ponds can be managed to store precipitation and minimize the need for expensive pumped ground or surface water. The practice of preventing overflow by capturing rainwater is common throughout the catfish industry. By maintaining pond depths at 6 to 12 in. below the height of the overflow structure, about 160,000 to 325,000 gal of storage capacity per surface acre of the pond is available to capture direct rainfall. When more water is stored, less water is released through overflows and smaller amounts of potential pollutants are released. Capturing rainfall and reducing the amount of overflow reduce the need for pumping additional water into a pond to compensate for water lost to evaporation and infiltration.

4.3.2 Trout

The production of trout represents the second largest sector of total AAP in the United States. In 2000, the total value of all trout sales, both fish and eggs, was $75.8 million (USDA, 2001). Idaho leads trout production in the United States and accounted for 53% of the total value of trout sold in 2000. Pennsylvania, North Carolina, and California are the other leading trout-producing states. Trout distributed for restoration, conservation, and recreational purposes, primarily from state and federal hatcheries, had an estimated value of $60.9 million for both eggs and fish distributed.

Trout are cultured both for foodfish production and to stock recreational facilities. Rainbow trout (*Oncorhynchus mykiss*) is the most common species cultured for AAP; however, brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) are also raised in AAP facilities. Trout belong to the group of fishes called salmonids, which are coldwater fishes that also include Atlantic salmon and Pacific salmon. Rainbow trout were originally native to North American rivers draining into the Pacific Ocean. Brook trout are native to an area that extends from the northeastern coast of North America, west to the Great Lakes, and south through the Appalachian Mountains. The brown trout, a native of European waters, was first introduced into the United States more than 100 years ago. Because of their popularity as both a sport fish and a source of food, all three species of trout are now widely distributed and cultured around the world (Avault, 1996b.).

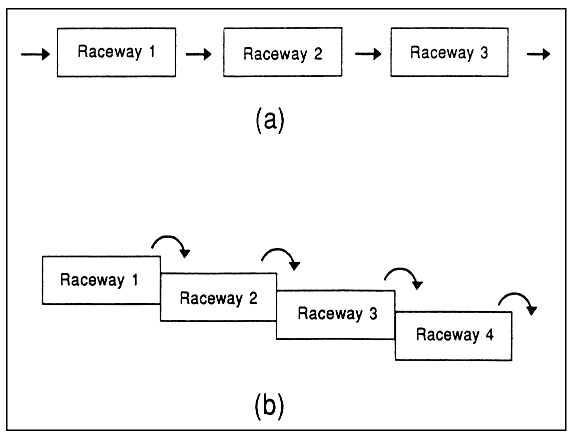
Rainbow trout culture became a farming business in the early 1900s, with a third of the farms operating as fee-fishing operations (Hardy et al., 2000). In Idaho, the first commercial trout farm was started in 1909 near Twin Falls. This area is known for its abundant spring water with a constant temperature from the Eastern Snake River Aquifer. In the early 1950s, trout farming expanded greatly, supported in part by the development of pelleted feeds. Farms no longer had to prepare their own feed, and production costs decreased. During the growth phase of the 1950s and 1960s, individual operators, including egg producers, growers, fish processors, distributors, and feed manufacturers, dominated the U.S. trout farming industry. Over the past decade, the industry has become more consolidated and vertically integrated. Today the most common trout farming businesses combine farming, processing, and sales. Egg production and feed manufacturing have remained specialized businesses.

Individuals and sport fisher groups originally began trout production to replenish wild stocks in natural waterways. These private hatcheries eventually evolved into the current state and federal hatchery system. State and federal hatcheries produce a number of species for restocking programs, while private commercial trout producers focus on food production of rainbow trout. Public hatcheries generally focus on the quality of the fish produced. Fish produced for enhancement purposes are produced to retain genetic integrity and characteristics needed to survive in the wild. Private hatcheries focus on maximum production to meet economic goals. Commercial producers emphasize genetic selection for fast growth and adaptation to culture conditions. These differences in goals are reflected in the different production strategies applied by public and private programs.

Trout production is the largest component of the inland stocking program. In 1982, some 200 million trout were stocked from more than 200 state and federal fish hatcheries, with states contributing roughly 80% of this total.

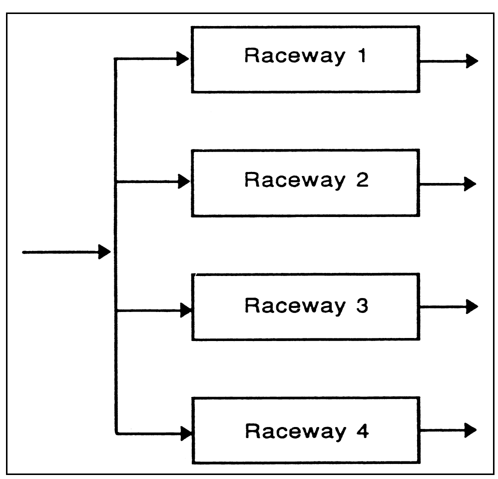
4.3.2.1 Production Systems

Most trout production facilities use flow-through systems. Flow-through systems are raceways, ponds, or tanks through which water flows continuously. Commonly, they are earthen or concrete rectangular troughs with varied dimensions and angles of pitch to allow a shallow stream of water to flow directly from one end to the other. The most common configuration for multiple raceways is either in series or in parallel. When constructed in series (Figure 4.3-1), water enters the upper raceway and then exits into a second raceway just downstream. This gravity-driven flow continues to the last raceway in the series. When raceways are constructed in parallel (Figure 4.3-2), the water source splits to flow through multiple raceways arranged parallel to each other. The water then exits the raceways into a common outflow pipe. Many large flow-through farms use a combination of the series and parallel configurations (Lawson, 1995a), shown in Figure 4.3-3. In North Carolina, raceways for trout production are typically 3 ft deep, 8 ft wide, and 40 to 60 ft long; most commercial facilities in North Carolina use concrete raceways (Dunning and Sloan, n.d.) In the southeastern United States, concrete raceways are also the most common rearing unit for commercial trout farms (Hinshaw, 2000). In Idaho the most common rearing unit is a concrete raceway with dimensions of 10 to 18 ft wide, 80 to 150 ft long, and 2.5 to 3.5 ft deep (IDEQ, n.d.).



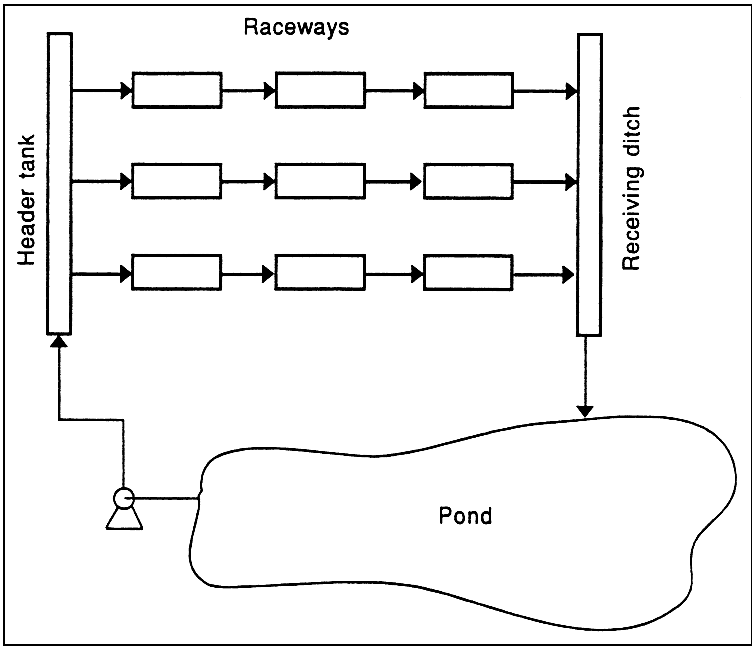
Source: Lawson, 1995a.

Figure 4.3-1. Raceway Units in Series (a) on Flat Ground and (b) on Sloping Ground



Source: Lawson, 1995a.

Figure 4.3-2. Raceway Units in Parallel



Source: Lawson, 1995a.

Figure 4.3-3. Combination Series and Parallel Raceway Units with Water Recirculation

4.3.2.2 Culture Practices

After fertilization and water-hardening, eggs are transported to incubation systems where they are incubated undisturbed until the eyed stage (about 14 d at a water temperature of 50 °F). Handling the eggs before the eyed stage damages and kills the sensitive embryos. There are several incubation methods for trout eggs. Eggs can be placed in wire baskets or rectangular trays suspended in existing hatchery troughs. Partitions between the trays force the water to flow up through the eggs from below before spilling over into the next compartment. Water is passed through the baskets or trays, and the newly hatched fry drop through the mesh to the bottom of the trough. The second method of incubation uses specially designed hatching jars placed in rows in hatchery troughs. The third method uses vertical flow incubators, which are widely used for trout eggs. Water is introduced at one end of the top tray and flows up through the screen bottom, circulating through the eggs. The water then spills over the tray below and is aerated as it drops.

Eggs hatch in the trays and remain there until they are ready to feed. Fungal growth can affect incubation. To prevent fungal growth, it is common to treat eggs with formalin (a 37% solution of formaldehyde) at a concentration of approximately 1 part formalin to 600 parts water for 15 min, every 1 to 3 d (Cain and Garling, 1993). Because of the specialized skill and labor involved in spawning, as well the high cost of maintaining broodstock, many trout farmers buy eggs for incubation rather than producing their own (Cain and Garling, 1993). In the North Central Region (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin), 92% of all purchased rainbow trout eggs come from outside the region, predominantly from western states. Farmers can also purchase fingerlings from hatching facilities that specialize in incubation and fry growout.

Trout emerge from eggs with a reserve of food in a yolk sac. At this stage, they are referred to as yolk-sac fry, or alevins, and they continue to live off and obtain nutrition from their yolks for approximately 20 d at 50 °F or 10 d or less at 60 °F (Hardy et al., 2000). When the fish begin to swim up to the surface, the thin yolk sac has been absorbed, and they begin to seek food actively. If incubation does not occur in a rearing trough, sac fry are transferred to a trough shortly after hatching. Troughs for raising fry are usually 12 to 16 ft long, 12 to 18 in. wide, and 9 to 12 in. deep. Fry are typically stocked at a rate of 1,000 to 2,000 fry per square foot of trough surface area. Flow rate and temperature also affect stocking rates. The water level in the fry trough should be kept shallow until the fish begin to "swim up." When fry reach about 2 in., they are ready for transfer to larger, deeper fingerling tanks. Fish are usually held and fed in fingerling tanks until they reach a length of about 3 in., and then they are moved to outdoor raceways for final growout.

The maximum amount of fish in pounds that a volume of water in a raceway can support is referred to as the carrying capacity. The carrying capacity of a culture unit depends on water flow rate, water volume, water temperature, dissolved oxygen concentration, pH, and fish size. From the time fingerlings (about 3 in.) are stocked in raceways until they reach marketable size (12 to 16 in.), they must be graded periodically to sort the fish into similar size groups and improve feeding efficiency. Trout are typically graded four times during a production cycle. Using a rectangular frame with evenly spaced bars of aluminum tubing, PVC pipe, or wooden dowels, the grader is placed in the inflow end of the raceway and moved toward the outflow end. This crowds larger fish in the outflow area so they can be removed and stocked in another raceway with fish of similar size.

Trout are harvested by using a bar grader as described above. As the fish are crowed into a small area of the raceway, they are dipped out with a hand net or a combination of a hand net and fish pump. The ease of harvesting fish from raceways makes this type of rearing unit very popular for flow-through systems. Round tanks use crowding screens specifically designed for the tank.

Feed Management

Early life stages such as fry are usually hand fed. Fry need many regular feedings throughout the day; they are often observed and fed only what they can consume in a short amount of time to prevent overfeeding. Fish in production raceways may be fed with mechanical feeders or demand feeders (IDEQ, n.d.). Mechanical feeders typically deliver a predetermined amount of feed to the fish. Commercial feeder designs range from stationary units to truck-mounted units. Automatic designs, like spring-loaded belts or auger-driven feeders, deliver small amounts of feed at any one time. This method restricts fish to a set amount of food each day. Demand feeders allow fish to feed to satiation. This method allows fish to choose how much feed is needed and when feed is released. Fish activate the suspended feeder, dispensing small amounts of feed, by bumping a rod that extends to the water.

In the United States, consumers expect trout to have white meat, so they are fed diets lacking the carotenoid pigments that give trout and salmon fillets their typically red color (Hardy et al., 2000). In nature, these pigments are present in their food through natural sources such as krill, yeast, or algae, or through astaxanthin, the carotenoid pigment found in the wild, produced by chemical synthesis. In Europe and Chile, trout are expected to have pigmented meat, so the feed for these fish is supplemented with astaxanthin.

Feed, including its manufacture, storage, and delivery to the fish, is one of the most important aspects of trout AAP waste management (IDEQ, n.d.). Research by Boardman et al. (1998) showed that using high-energy feed may reduce the amount of solids leaving the system. The study showed that effluents of basins receiving standard trout grower feed generally contained higher levels of total suspended solids (TSS) than those receiving high-energy feed. Further analysis showed that effluents of basins receiving the standard grower trout feed had lower levels of TKN than those receiving a high-energy feed.

Health Management

Bacterial gill disease (BGD) is one of the most common diseases of cultured trout (Piper et al, 1982). Sudden lack of appetite, orientation in rows against the water current, lethargy, and riding high in the water are typical signs of BGD. Crowding, mud and silt in the water supply, and dusty starter diets are stress factors that contribute to outbreaks of the disease. The most important factor contributing to BGD is the accumulation of fish metabolic wastes due to crowding. To treat the disease, facility operators correct unfavorable water conditions, reduce stress, and use constant flow treatments with salt (NaCl), or Chloramine-T at 8 to 10 mg/L (under an FDA-sponsored Investigational New Animal Drug (INAD) application) for 1 h for 2 or 3 d. Furunculosis, another common bacterial fish disease, is generally considered a disease of salmonids. Once an infected population of trout has overcome the disease, some of the survivors become carriers. Stress and poor water quality conditions can reduce the resistance of fish, and carrier fish can experience chronic or acute infections. Healthy rearing conditions, sanitation, and use of pathogen-free fish help control furunculosis. If the bacterium is sensitive to Terramycin (oxytetracycline), facility operators can use medicated feed. Facilites may also use Romet-30. Vaccination against furunculosis can also be effective (Plumb, 1994c).

Fish health management in rainbow trout farming is based on prevention; once a disease outbreak occurs, it is difficult to treat or control (Hardy et al., 2000). Farmers keep raceways clean, use high-quality feed, prevent overcrowding, minimize disease vectors, and vaccinate stocks. Vaccination has been very effective in preventing some important diseases in rainbow trout (Hardy et al., 2000). Birds are a common disease vector because they move from farm to farm and eat diseased fish. Most farms in Idaho use netting to restrict birds' access to trout raceways. Use of antibiotics delivered in feed to treat rainbow trout is not a common practice. Antibiotic use is limited by cost and by the regulation of their use in trout farming. Only two antibiotics (Terramycin and Romet-30) have been approved for use in the United States for fish, and they are not typically effective against many trout diseases. According to site visit reports conducted by EPA, several trout production facilities in Idaho use vaccination programs to prevent disease rather than treating sick fish with antibiotics (Tetra Tech, 2002a; Tetra Tech, 2002b).

4.3.2.3 Water Quality Management and Current Treatment Practices

Water Quality Management Practices

Flow-through systems require large inputs of high-quality, oxygenated water. In the trout culture industries in the northeast and northwest United States, freshwater springs are the most common source of water because of their relatively low and constant water temperatures (Lawson, 1995b). Water supplies may also come from surface waters such as streams, rivers, and irrigation returns. In western North Carolina, most water supplies come from surface waters that have been diverted for use by the facility (Tetra Tech, 2002a).

Concrete raceways have the advantage that there is no erosion of the sides, as happens with earthen ponds or raceways. This also means that these raceways can be operated at higher flow rates. The water flowing in delivers the needed oxygen to the fish while carrying away the dissolved metabolic waste products as the water exits the pond, or they are passed on to the pond below if raceways are positioned in series. These metabolic waste components must be kept within safe concentrations for the fish being raised. Concentrations of un-ionized ammonia-nitrogen need to be controlled to limit the impacts of this highly toxic compound.

Dissolved oxygen is another important limiting factor in flow-through systems. These systems often use gravity aerators to supplement the oxygen supply. Gravity aerators are often called waterfall aerators or cascades (Lawson, 1995c). They use the energy released when water loses altitude to transfer oxygen. Based on local topography, if a sufficient gradient exists, gravity fall is a common method for aerating flow-through systems. Man-made gravity aerators include components such as weirs, splashboards, lattices, or screens, which break up water to increase surface area and oxygen transfer. For example, facilities may use a combination of splashboards and weirs between raceways to create gravity aerators. Aeration or oxygenation can minimize the impact of dissolved oxygen as a factor limiting production. The greater the flow of water through the raceway, the more oxygen is delivered and the more fish can be supported.

In a study conducted by Boardman et al. (1998), three trout farms in Virginia were selected to represent fish farms throughout Virginia (Table 4.3-4). Sampling and monitoring (Table 4.3-5) at all three sites revealed that little change in water quality between influents and effluents occurred during normal conditions at each facility. Raceway water quality, however, declined during heavy facility activity like feeding, harvesting, and cleaning. During a 5-day intensive study, high TSS values were correlated with feeding events. TKN and ortho-phosphate (OP) concentrations also increased during feeding and harvesting activities. Overall, most samples taken during this study had relatively low solids concentrations, but high flows through these facilities increased the total mass loadings.

Table 4.3-4. Site Characteristics of Trout Farms

Characteristic	FARM		
	A	B	C
Average production (lb/yr)	59,965 – 80,027	59,965	175,045 – 250,002
Fish type	Rainbow, brook	Rainbow	Rainbow, brook, brown
# Raceways in use (total #)	3 (7)	14 (14)	24 (31)
Feeding practice	Automated (pull string)	Hand (measured)	Hand (measured)
Reported feed conversion ratios (FCRs)	1.6	1.6–2	1.2–1.8
Concrete/earthen-lined	Concrete	Both	Both
Water source	Spring	Spring	Spring
Labor	1 person	1 person	4–6 people
Pollutants regulated	TSS, NH_3-N, SS	TSS, BOD_5, SS	TSS, BOD_5, NH_3-N, SS
Treatments	Sediment traps	None	Sediment traps

Source: Boardman et al., 1998.

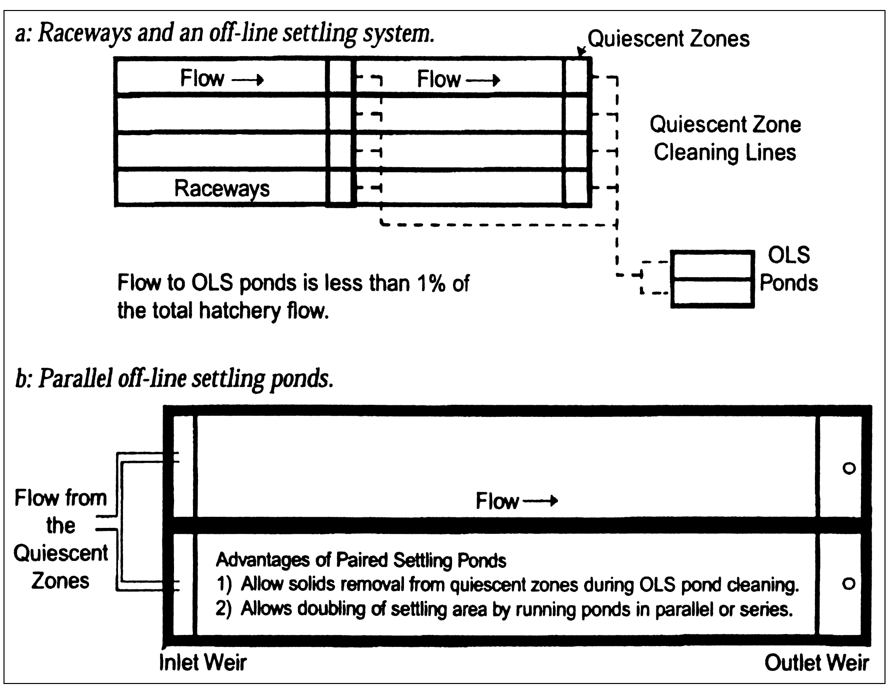
Table 4.3-5. Water Quality Data

Parameter	FARM A			FARM B			FARM C		
	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
Flow (mgd)	1.03–1.54 (1.18)			4.26–9.43 (6.39)			9.74–10.99 (10.54)		
DO (mg/L)	9.2–14.2 (10.6	3.2–13.3 (7.0)	5.7–9.5 (8.5)	8.2–11.5 (10.5)	5.8–10.8 (8.6)	6.8–9.6 (7.9)	9.4–10.6 (10.5)	4.8–9.7 (7.6)	7.2–9.4 (8.1)
Temp (ºC)	10.5–13 (12.2)	11.5–15 (13)	11–15.5 (12.9)	6–12.5 (9.7)	6–14 (9.1)	5–16.5 (11.4)	8.5–13.5 (10.5)	8–14 (11.0)	8.5–14 (10.4)
pH (SU)	7.1–7.4 (7.3)	7.0–7.4 (7.2)	7.3–7.8 (7.5)	7.3–7.6 (7.5)	7.2–7.6 (7.4)	6.9	7.3	7.1–7.6 (7.3)	7.8
TSS (mg/L)	0–1.1 (0.2)	0–30.4 (3.9)	0.8–6 (3.2)	0–1.8 (0.5)	0–43.7 (5.3)	1.5–7.5 (3.9)	0–1.5 (0.3)	0–28 (7.1)	4.1–62 (6.1)[a]
SS (ml/l)	0		0–0.04 (0.02)	0		0.01–0.08 (0.04)	0		0.04–0.08 (0.07)
BOD_5 (mg/l)	0–1.25 (0.7)	0.5–3.9 (1.5)	0.96–1.9 (1.3)	0–1.4 (0.5)	0.3–7.2 (2.1)	0.6–2.4 (1.2)	0–2.0 (1.1)	0.4–7.5 (2.5)	0.5–1.8 (1.3)
DOC (mg/L)	0.93–4.11 (2.1)	0.9–7.9 (2.9)	1.5–2.4 (1.9)	0.91–2.56 (1.6)	1.2–8.1 (2.7)	1.2–3.1 (1.9)	1.1–2.7 (2.0)	1.1–11.1 (2.4)	1.5–3.8 (2.3)
NH_3-N (mg/L)	0.6	0.2–1.1 (0.5)	0.5–0.6 (0.6)	0.2	0.06–1.1 (0.5)	0.45	0.03	0.03–2.2 (0.4)	0.02–0.17 (0.1)

[a] Two outliers were not included in the calculation of mean.
Source: Boardman et al., 1998.
Note: Averages are in parentheses.

Quiescent zones are the primary areas where solids are collected in a raceway. These zones are downstream of the rearing area, without fish, which allows bio-solids to settle undisturbed while intact and large in size (IDEQ, n.d.). Typically, quiescent zones are part of each trough or raceway; their dimensions account for the settling velocity of particles. The swimming activity of larger fish helps move solids downstream into settling zones. The most common method of solids removal from quiescent zones is through a vacuum head (IDEQ, n.d.). Usually, standpipes in each quiescent zone connect to a common 4- to 8-in PVC pipe, which carries the slurry of water and solids to the offline destination. In *Idaho Waste Management Guidelines for Aquaculture Operations* (IDEQ, n.d.), the state recommends cleaning quiescent zones as often as possible, with a minimum of twice per month on lower raceway sets and once per month on upper raceway sets. Last-use quiescent zones should be cleaned most frequently.

Offline settling (OLS) ponds are settling zones that receive the water and solids slurry from the quiescent zones (Figure 4.3-4). These ponds can be earthen or concrete and are the second settling zone in the solids collection system. Quiescent zones, in combination with OLS ponds, are the most commonly used solids collection and removal system for trout farming in Idaho (IDEQ, n.d.). Flow to OLS ponds is usually very small when compared to the total facility flow. OLS pond effluent is typically less than 1.5% of the total flow during daytime working hours and less than 0.75% averaged over 24 h. The depth of a typical OLS pond is 3.5 ft, but some are deeper. Depth is not required for settling efficiency but is required for solids storage. The Idaho Department of Environmental Quality recommends that, at a minimum, OLS ponds should be cleaned every 6 mo. In Idaho most trout production operators remove the solids from OLS ponds when TSS levels approach 100 mg/L. Many facilities in the state have several OLS ponds, which are linked together to improve solids collection. When one pond is undergoing solids harvest, the other is receiving solids from the quiescent zones. To remove the solids, the inflow is diverted to another OLS pond, and the supernate from the



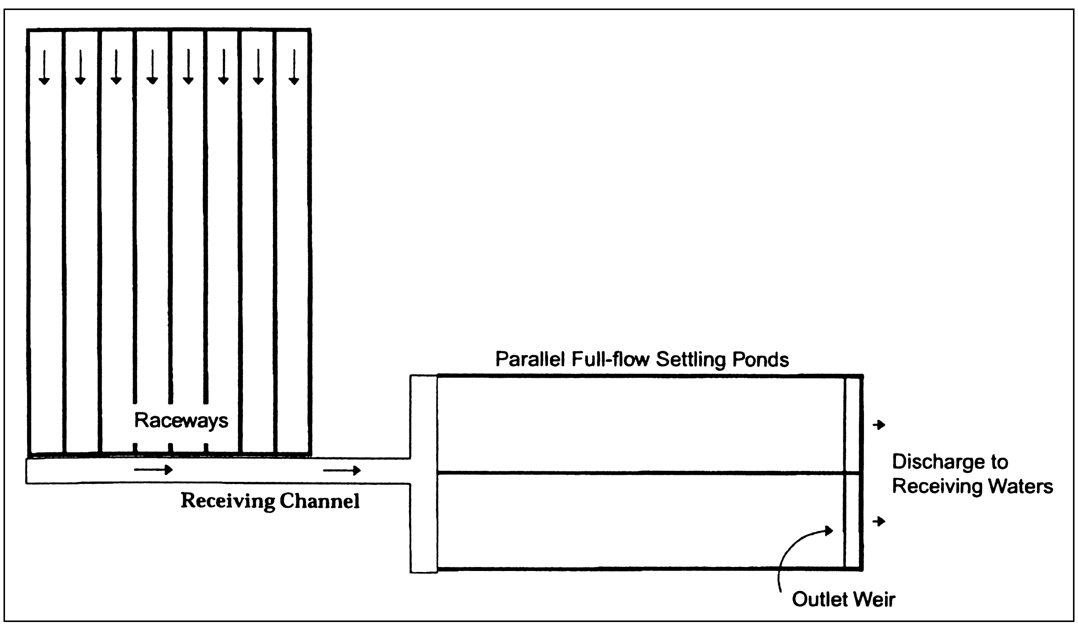
Source: IDEQ, n.d.

Figure 4.3-4. Offline Settling Ponds

pond being harvested is moved to an adjacent pond. Earthen ponds are allowed to dry for a few days, and the solids are removed by a backhoe from the pond bank. In a concrete pond, the OLS pond has a ramp where a front-end loader can enter the pond to remove solids.

Some trout facilities use full-flow settling (FFS) pond (Figure 4.3-5), which may not include quiescent zones or OLS ponds. The FFS system has one or two large settling zones, which collect the solids from the water flow for the entire facility. Instead of removing solids from individual raceways or troughs, the water from all of the rearing units combines and enters the FFS pond, where the solids are collected. FFS ponds are typically used by smaller facilities with low flow volumes.

In the study of Virginia trout farms by Boardman et al. (1998), waste solid accumulations in quiescent zones were monitored to quantify the capacity and trapping efficiency of the units. Solids were found to accumulate at a rapid rate (more than 7,800cm/d or 256 ft/d); however, the trapping efficiency of the units was found to be extremely low when taking into account the FCRs and typical utilization rates of production fish. High overflow rates, particle degradation, flow spikes, and high sludge banks led to scouring of waste solids and a point of maximum capacity for the sediment trap.



Source: IDEQ, n.d.

Figure 4.3-5. Use of Full-Flow Settling Ponds to Treat 100% of the Flow From the Fish Farm Before it is Discharged

Sludge Treatment and Disposal

Once solids are removed from OLS ponds or FFS ponds, they are stored or used in ways that minimize their impact on groundwater or surface waters. In Idaho, land application of collected solids to cropland has become the easiest and most widely adopted technique to dispose of wastes and recycle nutrients from trout production settling ponds (IDEQ, n.d.). Regulations vary from state to state, but most allow for aquacultural solid wastes to be applied to land because of minimal concentrations of metals, pathogens, and toxic substances in the sludge. The rate at which sludge may be applied to land varies based on soil type, plant type, odor issues, and sludge nutrient content.

Composting is another popular sludge disposal and treatment option (Boardman et al., 1998). When large areas of land are not available for land application or transportation costs for disposal are high, composting represents a good alternative (IDEQ, n.d.). Because of high costs, landfills are one of the least common means of disposing of solid wastes from CAAP facilities; however, some states are required to take their sludge to a landfill, where the states regulate the waste as industrial, rather than agricultural, waste (Boardman et al., 1998).

4.3.3 Salmon

Two distinct sectors influence salmon AAP: production for foodfish and production for stocking to restore wild stocks for conservation and recreation. In the United States, private salmon farming for foodfish production began in Washington State in the early 1970s with farms producing pan-sized coho salmon (*Oncorhynchus kisutch*) in marine net pens (Roberts and Hardy, 2000).

Public hatchery stocking programs are dominated by production of coldwater fish (salmonids). Most salmonids stocked in the United States are Pacific salmon released as smolts into various river systems connected to the Pacific Ocean. In the Columbia River Basin, more than 90 state and federal hatcheries raise and release roughly 190 million juvenile Pacific salmon annually (Schramm and Piper, 1995).

Atlantic salmon dominates commercial production in the United States. Although salmon was traditionally sold smoked or canned, today most salmon is sold frozen or fresh. According to the 1998 Census of Aquaculture (USDA, 2000), 45 farms produced salmon commercially in the United States, producing more than 110 million lb in food-size fish. In 1998 the salmon AAP sector generated more than $103 million in revenue (USDA, 2000). The 1998 Census of Aqaculture data show that three states, Alaska with 19 farms, Maine with 12 farms, and Washington with 9 farms, are the largest producers of salmon in the United States (USDA, 2000). Alaska, which prohibits private farming of all fish species, has 19 salmon hatcheries that are operated as private nonprofit corporations. They raise smolts and release them into the wild, where they are later harvested from the ocean in a practice called ocean ranching.

Both Atlantic and Pacific salmon belong to the Salmonidae family, which also includes trout and whitefish. Atlantic salmon has its own genus, *Salmo*, while the five primary species of Pacific salmon belong to the genus *Oncorhynchus*. In the United States, there are five species of Pacific salmon: pink (*O. gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), chinook (*O. tshawytscha*), and coho (*O. kisutch*).

Wild salmon begin their life cycle as eggs in the gravel of cold, freshwater rivers and streams. When females reach freshwater spawning grounds, they use their caudal fin to excavate a nest, or redd, in the gravel riverbed. Females deposit their eggs in layers as they are fertilized by the male salmon. The female covers the eggs with gravel and guards the nest for up to 2 wk. In 2 to 6 mo, the eggs hatch into translucent hatchlings called alevins and obtain nutrition from their yolk sacs. After 3 to 4 mo, the inch-long salmon fry emerge from the gravel and begin foraging for food in the river. As the fry grow into fingerlings, they move to a lake to mature as fingerlings before smoltification. Chum and pink salmon spend little time (1 to 3 mo) in freshwater before moving to sea. Chinook begin to move to sea within 6 mo, while coho usually stay in freshwater for up to 1 yr, and sockeye salmon stay in freshwater for 1 to 3 yr.

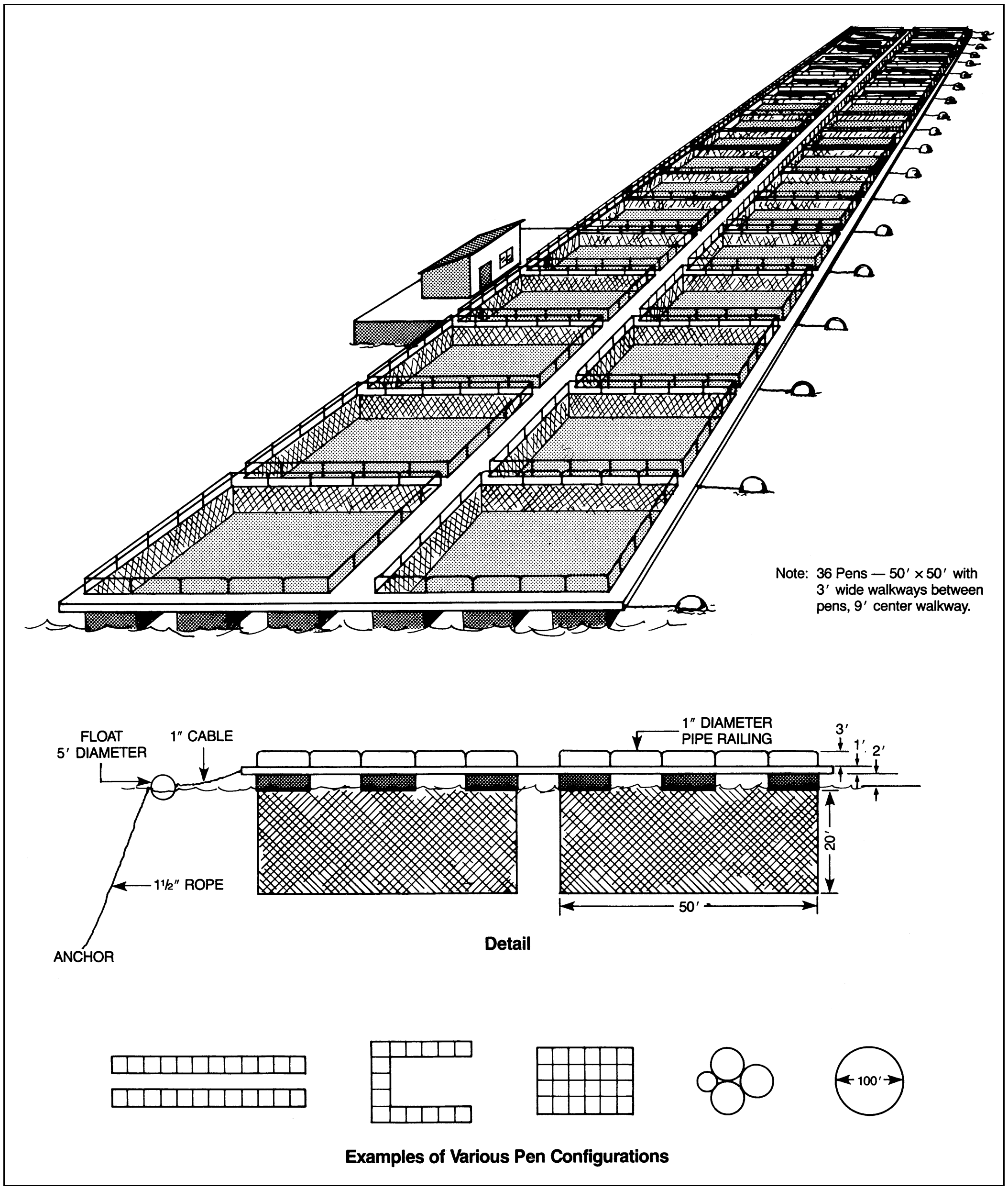
When they reach 2 in. in length, Pacific salmon begin feeding on insects, worms, and other invertebrates. As they develop dark vertical bar markings, they are called parr. At about 6 in, Pacific salmon begin moving to sea. The physiological changes salmon make to switch from a freshwater to a saltwater environment are collectively called smoltification. After smoltification, salmon remain in the sea for 1 to 5 yr, depending on the species, feeding and growing to sexual maturity and then returning to freshwater streams to spawn. Atlantic salmon parr may remain in freshwater for as long as 8 yr before moving to sea (Weber, 1997). Most salmon species die after spawning, but Atlantic salmon can spawn several times, returning to the sea between events.

4.3.3.1 Production Systems

There are two types of salmon AAP, salmon farming and salmon ranching (or ocean ranching). Salmon farming involves two phases: (1) the freshwater hatchery phase for the incubation of eggs and the raising of juveniles to the smolt stage and (2) the seawater phase, in which the salmon are grown out to market size, usually in floating pens (Clarke, 2000). Salmon ranching, which is practiced primarily in Alaska, is an alternative form of AAP that involves the release of smolts from hatcheries and the harvest of adults returning from the ocean.

The hatchery or freshwater stage begins when fertilized eggs are placed in hatcheries operated with oxygenated water. Salmon hatcheries generally use flow-through systems; some partial recirculation systems are used to conserve heat during egg incubation. Stacked trays, upwelling jars, or troughs may be used as egg incubators. The salmon life cycle makes it possible for fish farmers to raise juvenile salmon in land-based tank and raceway operations before growing them out in marine environment net pens or cages. Young fish are raised in upland hatcheries until they become smolts; on the west coast, however, parr are often placed in estuarine pens of reduced salinity, and some fish are raised to maturity in freshwater. Smolts are then transferred to net pens (i.e., salmon farming), where they remain for 1 to 2 yr until they reach market size. In Alaska, Pacific salmon (coho and chinook) are commonly raised in marine net pens for periods of 1 to 6 mo before release by public agencies or Native American tribes for enhancement projects. These fish are stocked as late parr or smolt and released after growing in the pens (i.e., salmon ranching). Holding salmon later than their normal smolt outmigration timing causes them to residualize in the nearshore waters, a technique used to enhance the sport fishery.

Generally, flow-through systems are used in the hatchery phase for the production of smolts. Raceways, tanks, or ponds are used to grow juvenile salmon until they undergo smoltification. Saltwater production normally begins after smoltification when the salmon are moved to net pen systems, which is the dominant production mode in saltwater salmon farming in coastal waters (Figure 4.3-6). The advantages of net pen cage farm systems in marine environments are relatively low capital cost per unit of rearing volume, reduced risks of stock loss through system failure and low dissolved oxygen, and access to large volumes of relatively high quality water without pumping costs (Karlsen, 1993). The primary disadvantages of marine net pen systems are increased risks due to storm damage; a complicated, lengthy, and expensive permitting process; a reduced ability to manipulate environmental conditions such as water temperature; and a potentially increased risk of predation and disease transmission from wild animals.



Source: WDF, 1990.

Figure 4.3-6. Example of a Fish Farm and Various Pen Configurations

4.3.3.2 Culture Practices

Broodstock may be collected from the wild or raised at a hatchery facility. The goals of a hatchery program raising salmon to be released into the wild are different from the goals of a hatchery raising salmon for commercial production. Domestication is an important characteristic for salmon raised for commercial production, but hatcheries want to avoid the domestication of salmon that are to be released into the wild (Pepper and Crim, 1996). For enhancement production, broodstock should be chosen from wild stocks. For commercial foodfish production, broodstock may be either collected from the wild or bred and raised at a hatchery facility.

There are several types of incubators, but generally they all have a container with sufficient water flowing through it and some type of screened enclosure to prevent eggs and larvae from being washed away (Billard and Jensen, 1996). After hatching, the salmon, now called alevins, have a large yolk sac reserve. As they near the completion of the yolk absorption, alevins leave the substrate and become free-swimming fry (Pennell and McLean, 1996). The timing of emergence occurs as the alevin complete the absorption of the yolk sac. Emergence is influenced by factors such as light, substrate type, and changes in temperature and oxygen concentrations.

The initial presentation of food is a critical stage in salmon culture because it marks the transition between incubation and raising (Pennell and McLean, 1996). The fry are then transferred to rearing units. Flow-through raceways, both earthen and concrete, are the most common rearing units used for juvenile salmon culture (Pennell and McLean, 1996).

Production for Release

Pacific salmon species dominate production for release. Alaska hatcheries incubate approximately 100 million sockeye salmon eggs per year. Most of the fry are stocked into lakes not accessible to wild salmon and allowed to develop into smolts under natural conditions (Clarke et al., 1996). Atlantic salmon are more challenging to cultivate for release because of their slower growth rates and large smolt size. Most smolt production hatcheries use elevated temperature to speed incubation, advance the time of the first feeding, and optimize feeding during the summer (Clarke et al., 1996).

Production for Commercial Culture

For Atlantic salmon, smolt production for either stock enhancement or commercial AAP is most efficient when done in the shortest amount of time to minimize costs (Clarke et al., 1996). Atlantic salmon usually require 2 yr of growth to reach the smolt stage in nature, but in commercial production, practices have allowed facilities to produce smolts in the first year by manipulating favorable temperatures, using high-energy feed, and applying good husbandry practices to minimize stress and disease (Clarke et al., 1996).

After smoltification, salmon for foodfish production are transferred to net pens for growout to market size. After the smolts are introduced to saltwater net pens, farmers monitor the progress of the salmon as they adjust to saltwater. Atlantic salmon, which can be especially sensitive, may need several days to resume proper feeding and acclimate to the net pens (Novotny and Pennell, 1996).

Harvest Practices

A decade ago, the growout phase in net pens required at least 2 yr. Today, salmon can reach harvest size in 10 to 15 mo after their transfer to net pens. Changes in feed formulation, feed pelletizing technology, the introduction of effective vaccines, and the domestication of farmed salmon stocks has shortened the time needed to grow salmon to harvest size (Roberts and Hardy, 2000). Today, after 12 to 18 mo in net pens, fish are ready to harvest at weights ranging from 5 to 11 lb (Novtony and Pennell, 1996). Because the salmon market is driven by quality of fish, farms emphasize quality control for harvest. Prior to harvesting, fish go through a period of starvation to reduce the fat content in the muscle tissue and the flora in the gut. This practice increases the shelf life of the salmon product (Novotny and Pennell, 1996). Fish are crowded into one corner of the pen and then pumped out with a fish pump or fish escalator and through a grader.

Feed Management

Feeding practices include hand feeding and a variety of mechanical feeders (Novotny and Pennell, 1996). Smaller cages with a low biomass of fish rely mostly on hand feeding. This requires cages placed nearshore with land access, a dock, or a small boat. Most net pen systems contain a large biomass of fish (e.g., 30,000 fish with a harvest weight of about 8 to 10 lb) and require the use of mechanical feeders. For net pens that are single structures without supporting walkways, barges and boats with feed blowers take feed to the net pens and feed, usually once or twice a day. Bad weather can impede this way of feeding. Other facilities use a stationary blower to deliver feed to each net pen in a group of pens. To control overfeeding, many facilities also use underwater cameras to monitor feed consumption (Nash, 2001).

Health Management

To prevent transmission of diseases, salmonid eggs are sometimes disinfected at the time of fertilization or at the eyed stage. The common treatment used is the iodophor Povidine with a 1% to 2% concentration of active iodine, which is similar to iodine but not as corrosive (Billard and Jensen, 1996). About 1 qt of solution with 100 ppm (active iodine) is applied to every 2,000 eggs for a period of 10 min, followed by a rinsing. Formalin is also used to prevent the spread of fungus (*Saprolegnia)* infections in eggs.

Freshwater salmonid diseases that have been observed in Pacific salmon hatcheries in the Pacific Northwest include furunculosis, bacterial gill disease, bacterial kidney disease, botulism, enteric redmouth disease, coldwater disease, columnaris, infectious hematopoietic necrosis, infectious pancreatic necrosis, viral hemorrhagic septicemia, and erythrocytic inclusion body syndrome. Pacific salmon hatcheries have also had outbreaks of a large number of parasitic infections like gyrodactylus, nanophyetus, costia, trichodina, ceratomyxosis, proliferative kidney disease, whirling disease, and ichthyophonis (Nash, 2001). Atlantic salmon are especially susceptible to furunculosis. The frequency of pathogen occurrences varies geographically. For example, a greater percentage of Alaska hatcheries tested positive for infectious hematopoietic necrosis, viral hemorrhagic septicemia, furunculosis, and ceratomyxosis between 1988 and 1992 than hatcheries located in other western states.

In the past oral delivery of oxytetracycline in the feed was the standard treatment. Today, the use of vaccines is a common industry practice. Immersion and injected vaccines have been so successful and so commonly used that antibiotic treatment is infrequent (Novotny and Pennell, 1996).

Several drugs have been approved by the FDA for use in salmonid AAP (FDA, 2002). Oxytetracycline is approved for use in Pacific salmon for marking skeletal tissue and for use in salmonids to control ulcer disease, furunculosis, bacterial hemorrhagic septicemia, and pseudomonas disease. Sulfadimethoxine is approved for use in salmonids to control furunculosis. Tricaine methanesulfonate is approved for use as a sedative or as an anesthesia, and formalin is approved for use in salmon culture to control protozoa (*Chilodonella, Costia, Epistylis, Ichthyophthirius, Scyphidia, Trichodina* spp.) and monogenetic trematodes. Formalin is also approved for use on salmon eggs to control fungi of the family Saprolegniaceae.

4.3.3.3 Water Quality Management

Hatchery Water Quality Characteristics

Like other flow-through systems, hatcheries for salmon smolt production rely on a clean water supply with a consistent temperature. Water quality management in the system, including the raceways, directly affects the quality of effluents and the volume of discharge released from the rearing unit.

In a study by Kendra (1991), salmonid hatchery effluents from 20 different facilities (11 state and 9 commercial) in Washington State were monitored during the summer low-flow season. Relative to source water, effluents from salmonid hatcheries had elevated levels for temperature, pH, solids, ammonia, organic nitrogen, total phosphorus, and oxygen demand. Cleaning events elevated concentrations of solids, nutrients, and oxygen demand (Table 4.3-6). Salmonid smolts in Washington are typically released from state hatcheries through the drawdown of the rearing unit or pond. Near the completion of the release event, samples indicated increases in solids, nutrients, and oxygen demand. As the pond depth decreased, fish crowding increased the amount of disturbed accumulated sediments.

This study (Kendra, 1991) also measured the impact of effluent on receiving waters and found that benthic communities below hatchery outfalls were different from those located upstream or farther downstream. Three of the four hatchery discharges in the benthic community study caused a depression of taxa sensitive to organic pollutants. Several mayfly and stonefly species were eliminated below the outfall, as well as elmid beetles. Some invertebrates, such as mollusc families, planarians, and oligochaetes, were enhanced by the hatchery discharge (Kendra, 1991). As a result of this study, the hatchery National Pollutant Discharge Elimination System (NPDES) permit limits in Washington were revised to include primary settling of solid wastes as a minimum requirement for all hatcheries.

Table 4.3-6. Hatchery Effluent Quality During Cleaning and Drawdown Events

Cleaning Events								
Variable	*Units*	*Yakima Trout Hatchery (Single Raceway)*		*Aberdeen Trout Hatchery (Multiple Raceway Composite)*		*Drawdown Event, Naselle Salmon Hatchery (Rearing Pond)*		
		Normal	*Cleaning*	*Normal*	*Cleaning*	*Prior to Drawdown*	*Drawdown Midpoint*	*Drawdown Near End*
pH	SU	7.4	7.6	—	—	7.6	6.7	7.1
Dissolved oxygen	mg/L	4.4	6.8	8.4	7.7	9.8	7.0	12.1
Total suspended solids	mg/L	1	88	1	12	7	30	94
Total volatile suspended solids	mg/L	0	69	<1	8	3	8	25
Settleable solids	mL/L	<0.1	2.5	<0.1	0.1	<0.1	0.3	1.1
Total Kjeldahl nitrogen	mg N/L	0.43	1.7	0.20	0.82	0.30	0.52	1.3
Total phosphorus	mg P/L	0.22	4.0	0.03	0.56	0.03	0.30	0.11
Chemical oxygen demand	mg/L	6	130	6	21	6	18	56
Biochemical oxygen demand (5-d)	mg/L	3	32	4	12	<3	3	—

Source: Kendra, 1991.

Net Pen Water Quality

In a study by the Washington Department of Fisheries (WDF, 1990) to evaluate the environmental impacts of commercial culture of fish in net pens, several water quality parameters were analyzed and potential impacts on the surrounding environment were evaluated. The EIS study by the Washington Department of Fisheries concluded that fish farms were not likely to have a significant impact on dissolved oxygen levels in Puget Sound except during the summer or autumn at sites that had low background dissolved oxygen levels and did not have adequate flushing (WDF, 1990). Overall, field measurements indicated that the area affected by low dissolved oxygen levels was less than 165 feet around the net pen structures.

Salmon net pens might also cause or increase phytoplankton blooms by increasing localized nutrient enrichment (Weston, 1986). Excessive phytoplankton growth can cause eutrophication. In a summary of experiments and modeling for phytoplankton impacts, the WDF assessment concluded that nutrients added by net pen operations were not likely to adversely affect phytoplankton abundance in Puget Sound. Model results for five 500,000 lb/yr farms showed an average increase of 0.0085 mg/L in nitrogen concentrations in winter conditions, or less than 1% increase in total nitrogen concentrations (Table 4.3-7). During the summer, the model predicted a 2% increase in phytoplankton biomass. The study did note, however, that poorly flushed bays are more sensitive to nutrient loading and that areas identified as nutrient-sensitive should limit total fish production. The study also recommended locating farms to minimize the overlap of near-field conditions from multiple farms.

Table 4.3-7. Effect of Five Fish Farms in an Embayment on the Nitrogen, Phytoplankton, and Zooplankton Concentrations for Summer and Winter Conditions Based on the Kieffer and Atkinson Model (1988)

	Dissolved Nitrogen (mg/L)		*Phytoplankton (mg/L)*		*Zooplankton (mg/L)*	
	Ambient	***Increase***	***Ambient***	***Increase***	***Ambient***	***Increase***
Winter	1.5	0.0085	0.012	0	0.003	0
Summer	0.012	0	0.186	0.004	0.186	0.004

Source: WDF, 1990.

In a technical memorandum prepared by NOAA (Nash, 2001), the report identified three key issues of net pen salmon farming in the Pacific Northwest that appear to carry the most risk: the impact of bio-deposits (uneaten feed and feces), the impact on benthic communities of the accumulation of heavy metals in sediments below the net pens, and the impact on nontarget organisms from the use of therapeutic compounds (pharmaceuticals and pesticides) at net pen farms.

Sediment deposits beneath net pen operations affect benthic communities. Biodeposits from uneaten feed and fish fecal matter settle onto sediments near net pens and affect the chemistry of the sediment and the benthic community (Nash, 2001). Sedimentation from salmon farms changes the total volatile solids and sulfur chemistry in the sediments in the immediate area surrounding the net pens. At sites with poor water circulation, deposit accumulations can exceed the aerobic assimilative capacity of sediments, leading to reduced oxygen tension and significant changes in the benthic community. The accumulation of organic wastes in the sediments can also change the abundance and diversity of the benthic infaunal communities.

The impact on benthic communities of the accumulation of heavy metals in the sediments below the net pens was also identified as a significant impact from salmon farming (Nash, 2001). Both copper, from marine antifouling compounds used on net pens, and zinc, from fish feeds, can be toxic in their ionic forms to marine organisms. Higher concentrations of sulfide in the sediment reduce the availability of both copper and zinc, which could make the observed concentrations near net pens nontoxic.

Results from a sampling program in the Broughton Archipelago in British Columbia confirmed that organic waste material was accumulating at a rate faster than the rate of decomposition beneath salmon net pen farms (Deniseger and Erickson, 1998). Sediments from 30 active fish farms were surveyed for physical and chemical characteristics. Researchers found that material accumulations can be significant (greater than about 1 ft). Sedimentation affects the benthic community by creating anaerobic conditions, which can persist for up to 1.5 yr or more (Erickson, 1999, personal communication).

Current Treatment Practices in Net Pen Systems

The same advantages that make the net pen systems favorable for production are also the characteristics that limit the use of treatment practices. Net pens are open systems that use natural water currents and tides for water supplies and flushing. Relative to pond and raceway facilities, net pen systems have several advantages, including the following: land requirements are minimal, construction and capital costs are generally lower, and there are virtually no pumping costs (Weston, 1992). From an effluent treatment perspective, however, net pen culture creates unique challenges. Because the effluent is not confined, treatment of dissolved wastes does not appear possible, and the treatment or removal of solid wastes has several technical difficulties (Weston, 1992). For the most part, the industry relies on dispersal and dilution of waste by natural water currents to maintain water quality for fish production and to minimize environmental impacts (Weston, 1992). The most effective way of reducing water pollution from net pen facilities is to minimize the loss of feed (Bergheim et al., 1991)

Most net pens are inspected by divers on a regular basis. The divers look for holes in the nets, dead fish, and fouling problems. State regulatory programs require benthic monitoring at many net pen sites to ensure that degradation is not occurring under or around the net pens. Other current requirements include video recordings in the spring and fall of the bottom beneath and adjacent to the cages; biennial sediment redox layer depth determinations (which measure sediment chemistry) during the fall; monitoring and reporting monthly feed use; and monitoring and reporting water quality, nutrients, and phytoplankton at farfield sites at four separate water depths. Prior to placement in pens, Atlantic salmon smolt/juveniles must be marked to link the identity of each fish to the facility. In Maine, reproductively viable non-North American Atlantic salmon stocks and transgenic salmonids are prohibited at CAAP facilities (USEPA, 2002).

BMPs required for fish pen operations in Maine include mortality removal; prohibition of disposal of feed bags or other solid wastes into U.S. waters; prohibition of discharge associated with pressure washing of nets; operation of facilities to minimize the concentration of net-fouling organisms; prohibition of biocides, tributyltin compounds, and storage of predator control or containment nets on the sea floor; minimizing the loss of unconsumed food and food fines from pens; reporting requirements for events such as fish kills, algal blooms, and confirmation of fish infected with infectious salmon anemia or other transmittable disease; and damage to a net pen that could result in salmon escapement. BMPs for disease control include using FDA-approved drugs. Unapproved drugs, including drugs in the INAD program, are prohibited. There is also a reporting requirement for all drugs discharged within 30 days of application (USEPA, 2002).

4.3.4 Striped Bass

Striped bass (*Morone saxatilis*) were originally produced and stocked in freshwater impoundments primarily for recreational purposes. Interest in hybrid striped bass for foodfish production in the United States began in the late 1970s. Production of food-size hybrid striped bass in the United States grew from about 1 million lb in 1990 to more than 10 million lb in 1996 (Harrell and Webster, 1997).

One of four *Morone* species, the striped bass is a major sport and commercial species native to the Atlantic and Gulf coasts of the United States, with stockings that have expanded its range throughout much of North America (Kohler, 2000a). The other *Morone* species are white bass *(M. chrysops*), yellow bass (*M. mississippiensis*), and white perch (*M. americana*). When a reproducing population of striped bass was discovered in landlocked Santee Cooper Reservoir in South Carolina, fisheries biologists were interested in stocking striped bass in reservoirs for sport fishing and as a predator to control underutilized forage species. *Morone* hybridization programs began in the 1960s and focused on combining characteristics of recreational trophy fish with adaptability to landlocked freshwater systems (Kohler, 2000a).

In 1965, Robert Stevens, of the South Carolina Wildlife Resources Department, initiated the production of hybrid striped bass by crossing striped bass with white bass. The first hybrid striped bass cross, of the striped bass female with the white bass male, was initially called the original cross-hybrid striped bass, but it is now referred to as the palmetto bass. The reciprocal hybrid striped bass cross of the white bass female with the striped bass male is called the sunshine bass. Of the various crosses and backcrosses made, only the hybrid of a striped bass crossed with a white bass has gained wide acceptance as a cultured species.

4.3.4.1 Production Systems

The industry has two main components: fingerling production and growout production. Some farmers are involved in both sectors, but most farms focus on either fingerling or growout production.

Hybrid striped bass are frequently sorted by size, or phases, to keep fish of similar size together and prevent cannibalism. Hybrid striped bass fry and phase I (approximately 0.2 in.) fingerlings in ponds feed on zooplankton until they reach about 0.2 in. in size, when they must be trained to accept artificial feeds to decrease the chances of cannibalism. Often fish are harvested, graded, and stocked into tanks for training on feed and then are reintroduced into growout ponds as phase II fish (Harrell, 1997).

Foodfish are often stocked to achieve maximum densities of about 5,000 to 6,000 lb/ac. They must be completely harvested before restocking. The ponds are drained between harvesting and restocking. To avoid draining the ponds, some farmers treat the ponds with a piscicide (a pesticide like Rotenone, used to kill fish) to eliminate remaining fish before restocking. Ponds are usually drained annually or biennially, depending on stocking size. Ponds are aerated to maintain dissolved oxygen and water quality. Fish are fed once or twice daily with mechanical feeders. Like catfish, hybrid striped bass production is concentrated in the southeastern United States and includes North Carolina, South Carolina, Florida, and Virginia.

Millions of *Morone* fingerlings are produced annually in state and federal hatcheries for stock enhancement and in private hatcheries as seed stock for foodfish production and fee fishing operations (Harrell and Webster, 1997). The fingerlings are stocked in earthen ponds, flow-through systems, closed recirculating systems, and net pens for growout. Today, foodfish production is based primarily on the production and raising of hybrid *Morone*. Although other striped bass hybrids have been created for potential foodfish production or have been used for stocking recreational programs, today only the palmetto bass and the sunshine bass are raised for production (Harrell and Webster, 1997).

In 1995 the Northeast Regional Aquaculture Center funded a survey conducted by the Striped Bass Growers Association and the University of Maryland to collect information from producers on the state of the striped bass industry (Harrell and Webster, 1997). The survey indicated that 66% of striped bass/hybrid striped bass producers use earthen ponds, 15% use tanks, 10% use net pens, and 9% use raceways for production. Of the producers culturing fish in tanks, most used flow-through systems (67%), while 22% used closed recirculating systems and 11% had the capability for both.

Stocking density for ponds differs between production of foodfish and production of fish for population enhancement efforts. Phase I fingerling ponds for population enhancement programs are stocked at a higher density, and fish are harvested at a smaller size than in ponds at foodfish growout operations. Stocking densities of striped bass larvae for population enhancement efforts range from about 50,000 to 600,000 per acre, and fish are harvested at sizes from 200 to 1,600 fish per pound (Harrell, 1997). In growout ponds stocking densities range from about 74,000 to 150,000 larvae per acre, with harvest sizes from 45 to 130 fish per pound (Harrell, 1997).

4.3.4.2 Culture Practices

Hatchery Phase

Unlike production of most cultured species, hybrid striped bass production typically relies on fertile wild broodfish to begin the production process. Striped bass broodstock are usually collected during spawning migrations in river headwaters above and below dams using electrofishing or gillnets (Kohler, 2000a). Another way to develop broodstock is to raise larvae or fingerlings in captivity until they reach reproductive age (Sullivan et al., 1997). Producers use hormones to induce spawning and then collect the eggs. Semen is then added to a mixture of eggs and water for fertilization. Embryos are incubated in aquaria, Heath trays, or MacDonald-type jars (Kohler, 2000a). Development is temperature-dependent; at 60.8 to 64.4 °F, the embryos begin to hatch 1 to 2 d after fertilization. By the fifth day, depending on the water temperature, the larvae absorb their yolk sacs. At this stage, they are known as fry until they metamorphose into juvenile phase I fish.

Phase I in Ponds

Successful phase I production requires a proper fertilization plan to ensure that the right zooplankton communities are present. Before phase I ponds are stocked with fry, they are drained, refilled, and fertilized with a mixture of organic fertilizers (such as cottonseed meal and alfalfa hay) and inorganic fertilizers (such as ammonium nitrate and phosphoric acid). The stocking density is dependent on the production goal. If the purpose of stocking is population enhancement, fry are stocked at a higher density to produce a greater number of smaller fish at harvest. Population enhancement programs need high quantities of fish to meet the management objectives of stocking a certain number of fish per acre of a reservoir or number of fish per mile of a river (Harrell, 1997). Fingerling producers stock fish at lower densities to produce larger fish. Producers buying fingerlings for growout want as large a fingerling as possible so that the fish can reach market size faster. Fry are fed salmon starter feeds by day 21 at a rate of 5 to 10 lb/ac/d. Producers use progressively larger feed sizes and increase the ration sizes as the fish grow. Phase I usually takes 30 to 45 d when fish reach total lengths of 1.0 to 2.0 in. and weigh about 0.03 oz (Kohler, 2000a). Survival rates greater than 15% for white bass and sunshine bass and greater than 45% for striped bass and palmetto bass are considered successful for phase I production. Phase I is the period during which the fish primarily feed on live food, mostly zooplankton; however, toward the end of this phase, the fish become more piscivorous. If supplemental feeding has not been initiated, cannibalism can cause high production losses.

Phase II in Ponds

Harvested phase I fingerlings are graded to separate out fish that are less than 1.0 in. total length (TL). Larger fish that are greater than 2.0 in. TL are also graded out to prevent cannibalism. The separated size groups are stocked in separate ponds. Unlike phase I, fertilizers are not used in phase II ponds. Because the fish are being fed manufactured feed, there is no need to stimulate zooplankton growth. Phase II describes striped bass and hybrid bass fingerlings from the time of phase I harvest until they are 1 yr old (Harrell, 1997). Many growout farmers purchase phase I fish and stock them in their ponds for phase II and phase III growout. Some producers market phase II fish; these fingerlings are primarily sold to government agencies for enhancement stocking or to net pen operations. Harvesting smaller ponds (< 2.5 acres) for phase II fish is similar to harvesting phase I fish. Ponds are drained down, and producers use seine nets to harvest the fish. This is a common practice for fish used for enhancement purposes, where fish are loaded directly into a transport unit (Harrell, 1997). Larger ponds are too expensive to drain and harvest at one time, so many farmers have started using large haul seines similar to those used by the catfish industry, and fish loading pumps to move fish between ponds. The pumps can be connected to graders that sort the fish by size and return smaller fish to the pond being harvested for further growout.

Phase III in Ponds

Phase III production is not common in enhancement production efforts, so most of the available information on actual production efforts in ponds comes from the industry itself, not from scientific literature (Harrell, 1997). Phase III growout is basically the second year production of striped bass and hybrid striped bass to a market-size fish. Most of the time, fish are harvested before the beginning of the third growing season, and the ponds are prepared to receive a new crop of phase II fish to repeat the cycle. Production ponds for final growout are usually larger than phase I and phase II ponds. Most phase III ponds are about 5 to 6 ac, with a range between 1 and 10 ac (Harrell, 1997). Since most growout operations do not have the facilities to completely draw down a pond and hold the harvest in tanks until the fish can be sold, producers harvest their ponds weekly or biweekly (Harrell, 1997). Haul seines are pulled through the pond, and fish are crowded into live cars. Producers can also use boom nets and then load fish into hauling trucks for transport to a processing plant. Fish can also be quickly killed with an ice brine or electrical shock; then the individually are graded and sorted into shipping containers.

Other Systems Used to Culture Hybrid Striped Bass

Flow-through systems and recirculating systems are also used to culture hybrid striped bass. For hybrid striped bass production, the advantages of flow-through or recirculating systems include better control over water quality and the health of the fish, growing seasons that are independent of climatic influences, easier fish handling and harvests, and flexibility for extended harvests, resulting in year-round sales.

A small percentage of hybrid striped bass production relies on freshwater cage culture methods, which are generally restricted to small-scale operations where pond water resources are not conducive to seining or ponds are already inhabited by other fish. Phase II fingerlings are stocked through openings in the cage top, which also allow for feeding and harvesting. With fish confined in the cages, the culturist can readily observe their behavior and health and more easily feed, manage, and harvest.

Feed Management

When hybrid striped bass are cultured in tanks or other confined systems, automatic feeders are often used to dispense feed at regular intervals. In larger systems, such as ponds, blowers are more commonly used to dispense the food across a wider area. Finding a cost-effective feed for striped bass and hybrid striped bass is very important because feeding cost can be one of the largest variable expenses of producing these species (Gatlin, 2001). Protein is an essential element in hybrid striped bass diets. It is important to maintain the proper ratio of protein to energy to ensure that the fish synthesize the protein and use it for growth instead of metabolizing it for energy. An excess of energy can reduce intake and result in decreased growth. Because protein is the most expensive component of many AAP diets, it is not economical to supply excess protein. In a feeding trial at Kentucky State University, one group of juvenile sunshine bass raised in cages was fed a diet with 41% protein and a protein-to-energy ratio of 99 mg protein/kcal energy, a second group was fed a diet with more protein and higher protein-to-energy ratios, and a third group was fed a diet with 41% protein and a lower protein-to-energy ratio. The results for the first two groups were similar. The decrease in protein in the third group's diet did not limit growth; however, it did cause increased fat deposition, which can cause a decreased meat yield in the final product (SRAC, 1998).

Fry and phase I fingerlings in ponds feed on zooplankton until they reach about 0.2 in. in size, when they must be trained to accept artificial feeds to decrease the chances of cannibalism. Often fish are harvested, graded, and stocked into tanks for training on feed and then can be reintroduced as phase II fish in growout ponds (Harrell, 1997). Because feeding observation is an important method of determining overall stock health, floating feed is most often preferred, except during the winter. In winter months, sinking feed is used so that fish will not have to rise to the surface for floating feed and be exposed to extreme temperature changes (Harrell, 1997).

Initially, phase II fish need to eat about 15% to 25% of their body weight per day, given in two separate feedings. Once the fingerlings reach 0.06 lb, daily feeding rates are gradually decreased to about 2% to 3% of their body weight in two separate daily feedings (Harrell, 1997). Tractor-drawn blowers are often used to deliver the feed at large operations, but demand and automatic feeders can also be used in pond culture (Hochheimer and Wheaton, 1997).

Although hand feeding and demand feeders have been used in some flow-through systems, automated mechanical feeders are most commonly used for both recirculating and flow-through systems. These feeders include towed blowers, stationary broadcast or blower feeders, and automated feed delivery systems (Hochheimer and Wheaton, 1997).

Health Management

There appears to be no difference between pure strains of striped bass and hybrid striped bass with respect to the fishes' susceptibility to diseases. Striped bass diseases are caused by viruses, bacteria, fungi, protozoa, and metazoan parasites. Except for viruses and parasitic worms, most of the infectious agents trigger diseases only when striped bass are stressed or injured. Since striped bass and their hybrids are extremely susceptible to environmental stress, the best ways to prevent infectious diseases are to follow good AAP practices and health management practices, including an emphasis on maintenance of good water quality, use of optimum stocking densities, provision of adequate feed and good nutrition, maintenance of optimum temperature, and use of proper fish handling procedures (Plumb, 1997).

Viruses known to infect striped bass include the lymphocystis virus, infectious pancreatic necrosis virus (IPNV), and striped bass aquareovirus. Because viruses do not severely threaten striped bass, little is done to control virus outbreaks. Fish infected with lymphocystis are simply removed from a production facility; it is not practical, however, to remove fish infected with IPNV. In either case, the facility can be dried thoroughly or disinfected with chlorine (200 mg/L) to kill any residual virus. There is not adequate information about striped bass aquareovirus to manage and control outbreaks (Plumb, 1997).

Bacteria cause the most serious debilitating infections of cultured striped bass. No bacterial diseases are unique to striped bass, but some bacteria have more serious effects on striped bass than on other cultured fish. Bacterial diseases affecting striped bass are Motile *Aeromonas* septicemia (MAS), *Pseudomonas* septicemia, Columnaris, Pasteurellosis, Edwardsiellosis, Vibriosis, Enterococcosis, Streptococcosis, Mycobacteriosis, and Carnobacteriosis (Plumb, 1997).

Control of bacterial diseases is best achieved through maintaining a high-quality environment and preventing conditions stressful to the fish. Sterilization of nets, buckets, and other production tools prevents cross-contamination between culture units. In recirculating water or open water supplies, ultraviolet (UV) radiation and ozone disinfection can reduce bacteria. Some drugs and chemicals have proven effective in treating bacterial infections in striped bass. Although none of the therapeutic agents are FDA-approved, bathing fish in sodium chloride (0.5% to 2% for varying times) or potassium permanganate (2 to 5 mg/L for an hour to indefinitely) and feeding fish medicated feed have been successful in treating bacterial infections. Medicated feed containing oxytetracycline (Terramycin) has been fed at a rate of 2.5 to 3.5 g/45 kg of fish per day for 10 d for treatment, and medicated feed containing Romet-30 (sulfadimethoxine-ormetoprim) has been fed at a rate of 2 to 3 g/45 kg of fish per day. Romet-30, however, might not be effective against Streptococcosis (Plumb, 1997).

Less is known about fungal diseases than about other diseases affecting striped bass because of the difficulty in identifying fungi and the fact that fungi are sometimes secondary pathogens to other diseases, injuries, or environmental stress. A few fungi that are known to cause infections in striped bass are *Saprolegnia parasitica* and related species, which cause "water mold," and *Branchiomyces* species, which causes "gill rot." Treatments of fungal infections with formalin, copper sulfate, and potassium permanganate have been used, but are often unsuccessful. Preventing fungal infections on eggs is possible through daily treatments of formalin at a rate of approximately 600 mg/L for a 15-min flush (Plumb, 1997).

4.3.4.3 Water Quality Management and Effluent Treatment Practices

Pond Systems

In a study in South Carolina (Tucker, 1998), water samples were collected and analyzed from 20 commercial hybrid striped bass ponds (Table 4.3-8). In an attempt to provide a broad representation of the industry, researchers included large and small operations, as well as ponds from both the coastal plain and piedmont areas of the state. Most of the commercial ponds sampled were freshwater ponds, but some saltwater ponds were also represented in this study. Overall, water quality parameters varied considerably from pond to pond. The 5-d biochemical oxygen demand of samples ranged from 2 mg/L to 60 mg/L, and suspended solids and volatile suspended solids were typically high but variable. Generally, concentrations for many of the variables were higher in the pond samples than in the water source samples.

Table 4.3-8. Means and Ranges for Selected Water Quality Variables from Hybrid Striped Bass Ponds in South Carolina

Variable	*Mean*	*Range*
Suspended solids (mg/L)	49	0–370
Volatile suspended solids (mg/L)	29	0–135
Biochemical oxygen demand (mg/L)	11.5	1.4–64.4
Kjeldahl nitrogen (mg/L)	7.1	0–97.0
Total ammonia (mg N/L)	0.95	0.02–7.29
Nitrite (mg N/L)	0.07	0–2.94
Nitrate (mg N/L)	0.36	0–4.61
Total phosphorus (mg P/L)	0.31	0–1.9
Soluble reactive phosphorus (mg P/L)	0.02	0–0.18

Source: Tucker, 1998.

The South Carolina study also compared water quality in fingerling ponds and growout ponds. Fingerlings were usually produced in smaller ponds, and although average aeration rates were similar for fingerling and growout ponds, water exchange was less in fingerling production. Biomass and feeding rates were lower in fingerling ponds, as were parameters associated with particulate matter and nutrients. Overall, the quality of effluents from hybrid striped bass ponds varied greatly from pond to pond. The study did not find any significant seasonal variation in quality, but researchers noted that the sampling protocol might have affected the measure of true seasonal effects. Concentrations of suspended solids, total nitrogen (including total ammonia), and biochemical oxygen demand were the water quality variables most elevated relative to the source water and would have the greatest impact on receiving bodies of water.

Other Production Systems

Water management in intensive systems, such as flow-through and recirculating systems, must address the full range of water quality parameters that could affect fish health and growth. Parameters to consider are continuous flow, adequate oxygen, consistent temperature, waste removal from the culture space, acceptable ranges of ammonia levels, control of parasite populations, and elimination of all other stress factors. Nearly all intensive systems include simple settling as part of the water management system to remove solids from the effluent stream, whether the water is to be reused in the system or discharged. Simple settling has proven adequate in removing the relatively dense waste solids from hybrid striped bass production (Hochheimer and Wheaton, 1997).

Because net pen culture practices rely on the water quality of the site at which the pens are located, there is little information on water management practices for hybrid striped bass production. Cages can be moved around within the pond, but generally they are of such small size that any water quality effects are negligible.

4.3.5 Tilapia

Tilapia are indigenous to Africa. In the 1940s they were introduced into Caribbean nations and, as a result, also entered Latin America and the United States. By the late 1950s the species had become the main focus of AAP research at Auburn University. Tilapia have been raised in most, if not all, U.S. states. Species cultured in the United States include Nile tilapia (*Oreochromis niloticus*), blue tilapia (*O. aureus*), Mozambique tilapia (*O. mossambicus*), Zanzibar tilapia (*O. urolepis hornorum*), and various hybrids of these species (Popma and Masser, 1999). In states where the growing season is not long enough to produce tilapia before winterkill occurs, production takes place in greenhouses or other buildings where supplemental heat is available. Since tilapia are still considered exotic, some states have restrictions on tilapia culture. In Arizona, California, Colorado, Florida, Hawaii, Illinois, Louisiana, Missouri, Nevada, and Texas, a permit may be required to culture tilapia, or the fish may be raised only if the species of interest appears on a list of approved fishes (Stickney, 2000c).

Most species of tilapia are mouthbrooders. Males construct nests in pond bottoms, females extrude eggs into the nests, males fertilize them, and females scoop them up in their mouths. Egg incubation (about 1 wk) and hatching of fry take place in the female's mouth, and fry stay in the mouth during yolk sac absorption. Once fry are ready to forage for food, they stay in a school around the female and go back into her mouth at any sign of danger. The fry remain in a school for several days after leaving the shelter of the female and stay around the edges of the pond where the water is warmest. Mozambique tilapia can mature as early as 3 mo after hatching; blue and Nile tilapia mature after approximately 6 mo (Stickney, 2000c).

Although many tilapia species are produced as foodfish, some species, such as *Tilapia zilli*, are herbivorous and have been used to control aquatic vegetation in irrigation canals and sewage lagoons. Other more colorful tilapia species have been marketed as aquarium fishes in the ornamental market. Some salt-tolerant tilapia and hybrids have become the focus of new interest in tilapia production in coastal ponds and marine cages in the Bahamas and some Caribbean nations (Stickney, 2000c).

Tilapia have become one of the most commonly cultured species in the world. The 1998 Census of Aquaculture estimated that 116 farms produced 11.5 million lb of tilapia, with a total of 137 farms producing food-size tilapia with a value of more than $23 million (USDA, 2000). The top five states for tilapia production in the United States are (in descending order) California, Maryland, Texas, Idaho, and Florida. Many culturists prefer to raise blue tilapia and Nile tilapia over the Mozambique tilapia because the former have better dress-out percentages, later maturity, and a more desirable flesh color (Stickney, 2000c).

4.3.5.1 Production Systems

Three primary types of production systems are in use at tilapia farms: ponds, flow-through production, and recirculating systems. Ponds and recirculating systems are the most common systems used for tilapia production in the United States, while flow-through systems are less common. In the southern United States, tilapia are sometimes raised in cages or net pens in lakes, large reservoirs, farm ponds, rivers, cooling water discharge canals, and estuaries; however, cage culture is a less common production system for tilapia.

Tilapia's intolerance of cold water limits its production potential in outdoor systems throughout most of the United States. Only southern Florida, Texas, Puerto Rico, Hawaii, and other Pacific islands have climates suitable for year-round outdoor pond production (Rackocy, 1989). Enclosed greenhouses are also used in some parts of the country, and in temperate climates tilapia must be grown indoors with heated water. Operators must either heat their airspace and influent water or use alternative sources of warm water, such as recycled wastewater that has been used to cool power plants or geothermally heated water (Rackocy and McGinty, 1989).

Ponds for tilapia production are similar to pond systems developed for other warmwater AAP species such as catfish and shrimp. Tilapia ponds require a design conducive to draining because fish harvest is difficult to perform without removing some or all water from the pond (Rakocy and McGinty, 1989). Tilapia are also cultured in flow-through systems. Circular tanks are the most common rearing unit for flow-through tilapia production because they have superior flow characteristics with fewer low-flow “dead spots” than rectangular tanks (Rakocy, 1989). Recirculating systems for tilapia production are similar to flow-through systems in terms of tank design, aeration, feeding, fish handling, and solids removal; however, water discharge is minimal with the operation of a recirculating system. Recirculating systems are widely used to produce tilapia for the live fish market because recirculating systems can be used for year-round production. Recirculating systems can also reduce water-heating costs and transportation costs because facilities can be located near large metropolitan market areas.

4.3.5.2 Culture Practices

Tilapia are often bred in recirculating systems because spawning is more easily observed and controlled in small tanks than in other systems. Ten to twenty days after tilapia broodstock spawn, fry begin to swim away from the mouth-brooding female fish. Fry can be collected with dip nets from the brood tank for stocking in nursery tanks (Rakocy, 1989).

Male tilapia are preferred for intensive food fish culture because they grow more quickly than female fish. Female fish divert energy from growth to producing eggs, and mouth-brooding females generally do not eat while holding young in the mouth. It is possible to produce all male fish with certain hybrids of *Oreochromis* species. Feeding newly hatched female fry with feed treated with male hormones inverts the sex of female tilapia to change them into reproductively functional male tilapia. Androgens such as methyl testosterone are used to invert the sex of female fry (Kohler, 2000b). Other methods include using a combination of hormones to produce "supermale" tilapia with double Y (YY) chromosomes instead of XY chromosomes. These YY males can be crossed with normal XX female fish to produce all male progeny. Researchers also have been experimenting with triploid (fish that have three sets of chromosomes and are unable to reproduce) and tetraploid fish (fish that have four sets of chromosomes that can be mated with diploid fish to produce triploids) to produce faster growing fish without the use of hormone treatments (Kohler, 2000b).

Fitzpatrick et al. (2000) treated fry with methyl testosterone at a concentration of 60 mg/kg in their feed for 4 wk beginning at the initiation of feeding. The treated fry were raised in three 16-gal tanks that contained no soil or gravel, 11 lb of soil, or 11 lb of gravel, respectively. Methyl testosterone water levels peaked at approximately 3.6 ng/mL (nanograms per milliliter) at 28 d after the onset of feeding. The concentration of methyl testosterone in water decreased to background levels (nondetect to 0.02 ng/mL) in 1 to 2 wk after the end of treatment with methyl testosterone-impregnated food in those tanks containing soil or gravel. The concentration of methyl testosterone in the tank containing no soil or gravel remained above background levels for 3 wk after the end of treatment with methyl testosterone-impregnated food (Fitzpatrick et al., 2000). Methyl testosterone degrades when exposed to light or high temperatures. In addition, bacteria and fungi can metabolize methyl testosterone; therefore the light, temperature, and microbial degradation in an outdoor pond setting degrade methyl testosterone.

The soil concentration of methyl testosterone in the tank with soil was 6.1 ng/g at the end of the 28-d treatment period. This level decreased to approximately 3 ng/g at 8 wk after the end of the treatment period (cessation of experiment). The methyl testosterone soil background level was 0.5 ng/g at the beginning of the experiment. The methyl testosterone levels in the gravel tank ranged from 22.9 to 99.2 ng/g of fine sediment at 8 wk after the end of the treatment period. The authors suggested that the slow degradation of methyl testosterone in soil and gravel might have occurred because the sediments acted as a trap for methyl testosterone (Fitzpatrick et al., 2000).

Stocking density for tilapia fry in flow-through systems can be maintained at as high as 750 fry per square foot. Once fish reach approximately 1 lb, recommended stocking levels drop to about nine fish per square foot (Rakocy, 1989). Most tilapia raised for foodfish are harvested when they reach 1 lb. Depending on the quantity of food and aeration inputs, tilapia can be raised from fry to harvestable sizes in 7 to 8 mo (Rakocy, 1989). Tilapia are more difficult to capture in seines than many other species of cultured freshwater fish because they have a tendency to jump over, or burrow under, nets (Rakocy and McGinty, 1989). Only 25% to 40% of tilapia in a small pond are usually harvested by seine nets. Complete or partial pond draining is usually necessary to harvest all the tilapia in a pond (Rakocy and McGinty, 1989). Tilapia in recirculating systems are usually harvested by crowding the fish into one part of the tank. The fish are then dipped out of the tank with nets or pumped out.

Feed Management

In pond production tilapia are able to feed on naturally occurring green algae, blue-green algae, zooplankton, benthic invertebrates, and decomposing organic matter. Many operators, however, supply tilapia with commercially prepared feeds using mechanical feeders to encourage faster growth.

Because tilapia can thrive on naturally occurring foods in ponds, they can be integrated into catfish pond culture during the summer months when water temperatures are above 50 °F. The stocked tilapia produce a second crop of fish without the producer incurring additional feed costs. Raising tilapia with catfish also might have the additional benefit of reducing off-flavor problems that can occur in traditional catfish farming because tilapia consume the blue-green algae that often cause an off-flavor problem (Rackocy and McGinty, 1989). Labor costs associated with sorting the catfish and tilapia at harvest, however, may reduce net profits for the operator.

Tilapia raised in flow-through systems are fed commercially prepared feeds using mechanical feeders. Adult fish are usually fed 3 to 6 times per day, at a rate of approximately 1% to 3% of their body weight per day. Under ideal conditions, with high-quality feeds, feed conversion ratios approaching 1.5 are possible with tank-raised tilapia (Rakocy, 1989). Tilapia in recirculating systems are also fed high-protein, commercially prepared feeds that optimize growth. Generally, the fish are fed using automatic feeders, which dispense food from above the tank.

Health Management

Three types of water-conditioning chemicals are commonly added to commercial recirculating systems for tilapia production. Sodium bicarbonate, or an alternative alkalinity source such as sodium hydroxide, is often added to replace alkalinity lost to nitrification in the biofilter (Loyless and Malone, 1997; Malone and Beecher, 2000; Tetra Tech, 2002c). Salt (sodium chloride) is added the system to prevent the occurrence of brown blood disease, which occurs in fish when water contains high nitrite concentrations. With this fish disease, nitrite enters the bloodstream through the gills and turns the blood to a chocolate-brown color. Hemoglobin, which transports oxygen in the blood, combines with nitrite to form methemoglobin, which is incapable of oxygen transport. Brown blood cannot carry sufficient amounts of oxygen, and affected fish can suffocate despite adequate oxygen concentration in the water (Tetra Tech, 2002c). Calcium chloride is used to simultaneously provide chlorides and increase calcium hardness in soft water areas.

4.3.5.3 Water Quality Management and Effluent Treatment Practices

Pond Systems

Tilapia become susceptible to disease when water temperatures are below 65 °F or when levels of ammonia, pH, and dissolved oxygen fall beyond recommended ranges. Tilapia are more tolerant of low dissolved oxygen levels than many other cultured foodfish species (Stickney, 2000c). Tilapia grown at low densities may not benefit from artificial aeration under normal pond conditions; however, supplemental aeration is recommended when growing tilapia in intensive pond culture systems with high fish densities (Papoutsoglou and Tziha, 1996; Rakocy and McGinty, 1989).

Tilapia ponds are drained to harvest fish, to adjust fish inventories, or to repair ponds. At the start of pond draining for harvest, pond water effluent characteristics can be expected to be similar to production water characteristics. Fish harvest by seining, however, stirs up sediments at the bottom of the pond. In fertilized tilapia ponds, sediments are likely to contain significant quantities of nitrogen and phosphorus. As draining and seining continue, effluent water quality can be expected to deteriorate (Tucker, 1998).

There is little mention in the literature of pond effluent treatment practices specifically for tilapia. If tilapia, however, are held in earthen ponds similar to those used for other freshwater fish, effluent management practices developed for catfish, crawfish, and hybrid striped bass can be expected to apply to tilapia culture. Tucker (1998) outlines some general pond culture effluent management guidelines: use high-quality feeds to reduce waste; provide adequate aeration and water circulation to avoid pond stratification; minimize water exchange during the growing season; leave excess storage capacity to capture rainfall and minimize overflow; harvest ponds without draining; and if draining is necessary for harvest, hold the last 10% to 20% of the water for 2 to 3 d prior to discharge to allow time for solids to settle.

Flow-through Systems

Flow-through systems must be managed to provide sufficient volumes of water to supply fish with oxygen and remove solid and dissolved wastes; therefore, these systems have a high demand for water.

There is little information concerning effluent treatment in tilapia flow-through systems; however, it is likely that common solids removal practices for other flow-through systems, including screens and settling basins, are common for tilapia flow-through production as well.

Recirculating Systems

Tilapia are hardy, disease-resistant fish, but when water temperatures are too low, they lose their resistance to disease and stop growing. In indoor recirculating systems, the optimal water temperature for tilapia production is 82 to 86 °F (Rakocy and McGinty, 1989). In temperate climates, water used in recirculating systems needs to be heated, especially during winter months. Alternatives to heating municipal or well water include using geothermically heated water (Rakocy and McGinty, 1989) or using heated effluents from electric power generating stations (Rakocy, 1989).

Many growers aerate recirculating systems with oxygen from liquid oxygen tanks leased from commercial suppliers. Tilapia grown in a recirculating system in North Carolina are supplemented with approximately 0.5 lb of liquid oxygen per pound of food added to the system (Tetra Tech, 2002c). High-density systems that use enriched oxygen sources must also provide for a means of carbon dioxide stripping to prevent pH depression in the circulating waters (Grace and Piedrahita, 1994). Some recirculating system design guidelines advocate direct aeration of tanks (Malone and Beecher, 2000; Sastry et al. 1999) or indirect aeration through the use of airlift pumps (Parker, 1981; Parker and Suttle, 1987; Reinemann and Timmons, 1989). In these blown air systems, oxygen addition and carbon dioxide stripping are reasonably balanced, and a separate carbon dioxide stripping process is not employed (Loyless and Malone, 1998).

Some of the water in recirculating systems must be discharged daily to remove solid wastes. In general, effluents from recirculating systems are more concentrated than wastewater from flow-through or pond systems. The total daily volume of effluents from recirculating systems is typically orders of magnitude smaller than effluents from flow-through systems of similar capacity that do not reuse water. Small discharge volumes make wastewater more economical to treat and in some cases alleviate the need to discharge to receiving waters. A recirculating system used to grow tilapia in North Carolina discharged such small quantities of wastewater that evaporation from an on-site aerobic waste lagoon exceeded the rate of wastewater inflow during summer months (Tetra Tech, 2002c).

4.3.6 Other Finfish

4.3.6.1 Largemouth Bass

Largemouth bass *(Micropterus salmoides)* are said to be the most sought after freshwater sport fish in the United States. State and federal hatcheries produced 21 million largemouth bass for sport fish stocking in 1995 and 1996 (Heidinger, 2000). It is estimated that commercial hatcheries produced approximately the same amount. A limited number of adult bass are used as foodfish by some consumers (mainly centered around large cities), but it can take 2 to 3 yr to grow bass to an adequate foodfish size.

The geographic range of largemouth bass is limited by temperature because they can be stressed at low temperatures (around 36 to 39 °F). These temperatures can occur in the winter in culture ponds located at the latitude of southern Illinois.

There are two subspecies of largemouth bass, the northern largemouth bass (*M. salmoides salmoides*) and southern Florida largemouth bass (*M. salmoides floridanus*). Genetic tests are required to tell the two species apart because they cannot be differentiated by a visual inspection. It is important to know which species one is working with during production because the southern subspecies is not as tolerant of low temperatures as the northern subspecies can be (Heidinger, 2000).

Production Systems

Various methods are used to produce largemouth bass. Most producers stock broodfish in ponds to spawn, although some are stocked in raceways or net pens, allowing the producer to be in greater control of production. Ponds are usually rectangular and less than 6 ft deep with no obstructions. Ponds are drained and completely dried in the fall to get rid of predacious insects, fishes, and diseases. Some operators sew winter rye in the pond to serve as an organic fertilizer after spring flooding. Agricultural lime can be added if the pond bottom soil is too acidic. Ponds should not be filled more than 14 d before stocking to prevent the buildup of predacious insects. Well water or surface water, which is filtered through 52 mesh/in. saran socks, are both acceptable for filling the ponds (Davis and Lock, 1997).

Culture Practices

Fry are left in the spawning ponds or moved to rearing ponds and fed zooplankton and aquatic insects. When the fish are fingerlings, they are raised at a low density on insects, or they can be trained in tanks to eat a prepared diet. Fingerlings (1.5 to 2.0 in.) are seined from nursery ponds, graded to uniform sizes, and stocked in round or rectangular flow-through tanks for feed training. Stocking density can be high, with a range from 200 to 500 fish per cubic foot (Tidwell et al., 2000). Fingerlings that are trained to eat the prepared diet grow faster than those feeding on insects, and the trained bass can then be moved to ponds, net pens, or raceways until they reach the desired size.

Bass are most often harvested by trapping, seining, or draining the pond. Fingerlings are generally harvested 2 to 4 wk after stocking, when they are approximately 1.5 in. in length, to lessen the chances of cannibalism. Although cannibalism is possible at any time, it is more likely to occur if fry are stocked at different ages and sizes and if there is a shortage of food. If at any time it is found that no appropriate invertebrates are present in the pond as a food source, the bass must be harvested regardless of size (Heidinger, 2000).

During training periods in tanks, largemouth bass are extremely susceptible to external parasites and the bacterial disease columnaris (caused by *Cytophagus columnaris*). Affected fish are treated immediately through medicated feed (terramycin). The use of salt baths of 0.5% to 1.0% for up to 1 hr is another practice used to reduce stress from handling and grading and to reduce the incidence of infectious diseases (Tidwell et al., 2000).

4.3.6.2 Smallmouth Bass

Smallmouth bass *(Micropterus dolomieui)* are popular sport fish found in many parts of the United States and are essentially nonmigrating fish. The species requires growing temperatures from 50 to 70 °F and spawning temperatures of 58 to 62 °F; the upper lethal temperature reported is 95 °F (Illinois-Indiana Sea Grant, n.d.). Ponds are the most common production system used for smallmouth bass culture (Illinois-Indiana Sea Grant, n.d.).

4.3.6.3 Carp

Several species of carp (family Cyprinidae) have been cultured in the United States. The government stopped stocking common carp (*Cyprinus carpio*) in the United States in the late 1800s because of problems associated with the species, such as damage due to erosion caused by the fish digging into the pond banks. Many reproducing populations, however, became established from early stocking programs and are still plentiful today. Although common carp are cultured as foodfish in other countries, there is a very small demand for them as foodfish in the United States. The fish have many small bones and often have poor flavor. There is a very small amount of commercial production of bighead carp (*Aristichthys nobilis*) and silver carp (*Hypopthalmichthys molitrix*), but that production is insignificant. Various carp species are banned in some U.S. states because they are considered to be exotic species.

The grass carp (*Ctenopharyngodon idella*) is commercially produced in the United States primarily for use in controlling aquatic vegetation. This species is very controversial because of concerns that it might also consume desirable vegetation and reproduce and become established in areas where it is not desired. Since the species is banned in many states and controversial in others, commercial producers began producing triploid grass carp (fish that have three sets of chromosomes and are unable to reproduce). Triploid grass carp are beneficial in controlling vegetation, and they die after a few years, so the decision can then be made whether to restock. Some states that had banned carp have made exceptions and allow stocking of the sterile triploid grass carp as long as the producers can certify that the fish are 100% triploid (Stickney, 2000a).

Culture Practices

Production of sterile triploid grass carp includes subjecting fertilized eggs to a pressure treatment that makes the eggs hold onto an extra set of chromosomes. The process involves placing the eggs in a stainless steel container and subjecting them to 8,000 psi (pounds per square inch) of hydrostatic pressure. The eggs hatch after an incubation period of 2 to 3 d, and the fish feed off of their attached yolk sacs. After 3 d, the fish can be fed hard-boiled egg yolks followed by commercial fish food and brine shrimp larvae as they grow. After a week in the hatchery, the young fish should be transferred to larger ponds, which should be fertilized to encourage zooplankton growth for a food source. After the fish reach approximately 1.5 in. in length, they begin to eat green plant material. The fish can undergo blood testing to determine whether they are triploid and sterile when they are 2 to 3 in. in length (Imperial Irrigation District, 1998).

4.3.6.4 Flounder

The summer flounder (*Paralichthys dentatus*) is a foodfish found along the east coast of the United States, from Maine to Florida (Bengtson and Nardi, 2000). The winter flounder (*Pseudopleuronectes americanus*) is a foodfish found along the east coast of North America, from the State of Georgia to Labrador, Canada. The species has been exploited for more than a century and is now considered overexploited due to its decline over the past 20 years. Hatchery production of winter flounder was first attempted in the late 1800s by the U.S. Fish and Fisheries Commission in an attempt to try to rebuild wild populations that were in decline. Those hatcheries released tens of millions of larvae before closing in the 1950s. Some of the techniques developed at those hatcheries are still in use today, now that declining stocks, coupled with a demand for quality flatfish, have once again motivated attempts to culture winter flounder (Howell and Litvak, 2000).

Production Systems

Commercial hatchery production of summer flounder in recirculating or flow-through tanks began in 1996, after 6 yr of government funding for research and development for cultural practices of the species. So far, only wild-caught broodstock have been used in commercial production, but hatcheries are working on domesticating them (Bengtson and Nardi, 2000).

Researchers and fish culturists of winter flounder have looked to information on production techniques for summer flounder for guidance. There are, however, some differences in culture techniques for the two species. Hormonal injections to induce spawning seem to be used more in winter flounder production than in summer flounder production. Static, flow-through, and *in situ* systems have all been used to raise winter flounder larvae, though static systems have been used only in research, not for commercial production. In larval flow-through systems, 100-L circular tanks are supplied with seawater that has been filtered and treated with ultraviolet light and kept at ambient temperatures and salinities. One *in situ* system was tried in Rhode Island with favorable results. It consisted of an open-mesh enclosure (406 ft^3 in size) suspended from a surface flotation collar. The mesh size was small enough to keep larvae in while still allowing their natural food to enter the enclosure. The estimated time for growth to market size is 2 to 4 yr. This time might be shortened in an AAP setting due to optimal fixed conditions used there, and the growout systems used would be similar to those for summer flounder (land-based tanks or raceways and net pens) (Howell and Litvak, 2000).

Culture Practices

Ideally, captured summer flounder broodstock are held for several months to allow them to adjust to their new surroundings and nonliving food diet before spawning is initiated. Some hormonal injections have been tried to induce spawning, but the most widely used method is hand-stripping the ripe fish. It is a high priority to develop methods for natural spawning since hand-stripping fish is highly stressful to the fish and might not be the best method for gathering the highest-quality eggs. After eggs and milt are stripped from the females and males, the gametes are combined in beakers where fertilization takes place. The embryos are placed in cylindrical containers of seawater. Hatched larvae can be taken from the incubation containers and put into rearing tanks, where they feed on rotifers. Survival rates are higher in rearing tanks to which algae have been added.

After larvae go through metamorphosis and settle to the bottom of the rearing tanks, they should be transferred to juvenile rearing tanks where they can become accustomed to an artificial diet and grow out to about 2 g before being netted and graded into larger tanks. Tanks may be round or square and range in size from 106 to 212 ft^3. Raceways should have rounded corners (known as D-ended). Regular cleaning of tanks and removal of uneaten feed and feces are extremely important.

Summer flounder can grow to about 5 g in five mo and are then ready for transfer to a growout operation. It has not been determined what systems and procedures work best for growout production, but recirculating systems and net pens have both been tested by certain companies. The U.S. government has funded some of those projects and hopes to compare growth and quality of the fish grown in the two types of systems, as well as qualitative and quantitative cost production differences for the two systems. The estimated time for growth to market size is 24 to 28 mo. (Bengtson and Nardi, 2000).

4.3.6.5 Paddlefish

Paddlefish *(Polyodon spathula)* are prehistoric fishes used as foodfish and as a source of eggs, or roe, for caviar. They are found in 22 states on the Mississippi River Basin and the adjacent Gulf Coast drainage. Overfishing, habitat modification, and contamination by polychlorinated biphenyls (PCBs) and chlordane have caused paddlefish numbers to decline. Paddlefish are protected against illegal roe collection through their listing on the United Nations' Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES).

Production Systems

Paddlefish can be raised in ponds or raceways. In pond production, survival rate ranges from 30% to 80%. In raceways, the survival rate increases to approximately 50% to 80%. Paddlefish broodstock are usually obtained from the wild because they take 7 to 9 yr to mature. They are generally raised in circular tanks with an average diameter of 8 ft, allowing them to swim continuously and aerate their gills; however, tanks can be larger.

Culture Practices

Approximately 2 wk before propagation, ponds to be used for paddlefish fry are completely drained and dried. After propagation, the ponds are filled with water from a well or from a reservoir that filters water through a saran sock. Organic fertilizers, such as rice bran or cottonseed, soybean, and alfalfa meals, are recommended for use in the nursery ponds to achieve a total nitrogen amount of 40 lb/ac. During the initial fertilization period, large zooplankton such as *Daphnia* species should be inoculated into the pond at a concentration of eight *Daphnia* per gallon. It is recommended that ponds be covered with netting to prevent bird predation of fry.

Propagation of paddlefish can be achieved artificially. The fertilized eggs are placed in incubation jars, where fry hatch in approximately 6 d. The fry absorb residual yolk in 5 to 6 d, after they are ready to eat external food such as *Daphnia*. Once water temperatures are higher than 65 °F, fry can be stocked at a rate of 25,000 fish/ac in the prepared (fertilized) earthen ponds, where they feed on the *Daphnia* or insect larvae. At the age of about 5 to 6 wk old, the fry's gill rakers develop, allowing them to filter-feed. Their diet can be supplemented during this time with trout/salmon crumbles (50% protein) at a rate of 15 lb/ac, and after about 3 to 4 wk, when the fish are 3 in., they can eat 1/16-in. extruded pellets. In about 6 mo, fish can grow to up to 14 in. long and 0.33 lb in weight. The fish can be harvested easily with gill nets or seines.

Paddlefish fingerlings (less than 10 in.) can also be cultured in raceways or flow-through systems. If groundwater is used, it should be aerated and heated to more than 72 °F. Surface water may also be used, but it needs to be filtered and also aerated and heated if needed. Because strong sunlight can cause sunburn and mortality in paddlefish, outdoor raceways should be covered with 95% shade cloth, which may also offer some protection against bird predation. Like fry raised in ponds, fry in raceways can be trained to eat a sinking diet of trout/salmon crumbles (more than 50% protein), and after about 3 to 4 wk, when the fish are three in. long, they can eat 1/16-in. extruded pellets. The pellets can be provided by automatic feeders every 15 to 20 min for about 7 to 10 d; then both automatic and hand feeding can be used to feed every 2 h until the fish are stocked into ponds or reservoirs.

Initially, fry can be stocked in raceways at eight fish per gallon, but as they grow, fish should be reduced to lower concentrations to prevent crowding. After 2 wk, fry should be about 2 in. in length and should be reduced to 2.5 fish per gallon. At 4 wk after stocking, fish should be about 4 in. and should be reduced to 0.75 fish per gallon. If fish start "billing"—swimming at the surface with their paddles out of the water—they are demonstrating that they are stressed by high densities. Reducing densities generally stops this behavior (Mims et al., 1999).

4.3.6.6 Sturgeon

Atlantic, shortnose, lake, and white sturgeons (*Acipenser oxyrhynchus, A. brevirostrum, A. flurescens,* and *A. transmontanus*, respectively) are prehistoric anadromous fish used as foodfish and a source of roe for caviar. Sturgeons were once abundant, but habitat modification and overfishing, combined with the species' slow reproductive rate, have dramatically reduced sturgeon populations (Friedland, 2000). White sturgeons are found in North America from Ensenada, Mexico, to Cook Inlet, Alaska (PSMFC, 1996), while Atlantic sturgeons are found from Florida to Labrador, Canada, and shortnose sturgeons range from Florida to New Brunswick, Canada (Friedland, 2000).

Production Systems

Sturgeon culture facilities are usually land-based tank systems. Producers can use recirculating systems during different production cycle phases. Sturgeon producers can also use gravity-flow linear raceways and discharge water to water bodies, preventing the escapement of cultured fish through the use of screens and settling ponds (Doroshov, 2000).

Bird predation is a significant problem in pond culture, especially for small sturgeons. Netting over ponds can help prevent bird predation, but recirculating systems or flow-through systems may be more economical for the growout of small sturgeons to market size. Larger sturgeons (1 lb or larger) are less vulnerable to bird predation due, in part, to the fact that the larger fish are almost entirely benthic (Bury and Graves, 2000).

Culture Practices

Sturgeon culture is difficult because of the complexity of replicating the species' natural spawning and raising activities. Minor surgery is required for internal examination of the fish to determine their sex and level of maturity, and eggs must be closely monitored to determine when they can be successfully fertilized (Government of British Columbia, n.d.).

Migrating Atlantic sturgeons are captured with gill nets, transported to hatcheries, and placed in either 0.25-ac freshwater earthen ponds or round fiberglass tanks. The fish are held for 12 to 13 d before spawning is induced by intramuscular injections of acetone-dried or fresh sturgeon pituitary gland extract. Eggs and sperm are mixed for 1 to 2 min, and fertilized eggs are stirred and washed for 10 to 30 min before being placed in MacDonald hatching jars. Yolk sacs are absorbed by fry 9 to 11 d after hatching, and the fry are then fed a diet of ground beef liver mixed with salmon mash, supplemented with live *Artemia* nauplii (Conte et al., 1988).

Lake sturgeons can be artificially spawned and then raised in floating cages or net pens. Spawning lake sturgeons are dip-netted from the Fox and Wolf Rivers in central Wisconsin. Sperm and eggs are collected from the fish, and the fish are then released. Eggs are fertilized and placed in MacDonald hatching jars. The fry absorb their yolk sacs within 10 d after hatching, after which the fry actively swim and feed on live brine shrimp nauplii. When the fry reach a length of about 1 in., they begin feeding on larger zooplankton (Conte et al., 1988).

Shortnose sturgeons are captured with gill nets or by electro-fishing and transferred to cylindrical tanks at the hatchery. Females are held for 3 to 4 wk, and males up to 6 wk, before spawning is induced by intramuscular injections of acetone-dried or fresh sturgeon pituitary gland extract. Eggs and sperm are collected and mixed, and fertilized eggs are incubated in MacDonald hatching jars or Heath Techna trays. Eggs are treated daily with formalin (1,670 mg/L for 10 min using a constant-flow method) to prevent fungus development. Larvae are raised in fiberglass and aluminum troughs. The troughs are 8 ft long, 1.5 ft wide, and 8 in deep, and they are connected to a flow-through freshwater system, which has regular applications of formalin (1.775 mg/L for 1 h) and occasional applications of streptomycin/penicillin. After 1 wk, larvae are fed live *Artemia* nauplii and salmon starter meal. After the larvae absorb their yolk sacs, ground beef liver is added to the diet as are supplemental experimental feeds and commercial semi-moist and dry rations.

Juvenile shortnose sturgeons are raised in 0.5-ac outdoor ponds (mean depth about 5 ft) where they feed on the ponds' benthic fauna and supplemental dry rations. They can also be raised indoors in 12-ft-diameter, 2.5-ft-deep fiberglass tanks connected to a freshwater recirculating system, where they feed on beef liver, squid, earthworms, polychaete worms, dry salmon and trout rations, experimental diets, and later on trout crumbles. Tanks are preferred because producers have more control of the water quality in tanks than in ponds.

Adult shortnose sturgeons are held in 0.5-ac ponds or cylindrical and raceway tanks (with a volume of 190 to 2,300 gal) supplied with recirculated water. Tank-held adults feed on fish, squid, molluscs, crustaceans, worms, and beef liver; pond-held adults do not receive supplementation (Conte et al., 1988).

Bacterial agents that cause diseases in sturgeon include *Aeromonas hydrophilia*, *A. sobria, Pseudomonas* spp., *Edwardsiella tarda*, *Yersinia ruckeri*, *Streptococcus* spp., and, rarely, *Flavobacterium columnariae*. Factors that may predispose cultured sturgeon to bacterial diseases include stress factors, such as handling, and water quality problems, such as low dissolved oxygen levels, traces of hydrogen sulfide, and accumulation of organic loads on the bottom of holding tanks. *Streptococcus* spp. can be treated with erythromycin (100 mg/kg body weight daily for 10 d), and *Edwardsiella tarda* can be treated with daily oxytetracycline baths (Francis-Floyd, 2000).

4.3.6.7 Sunfish Family

Sunfish are produced for sport and foodfish, forage fish for predators including bass, and stocker fingerlings for recreational ponds. The sunfish family *(Centrarchidae)* is exclusive to North America and includes 30 species, the most popular of which are the bream (*Lepomis* spp.) and crappie (*Pomoxis* spp.).

Species from the genus *Lepomis* are commonly referred to as bream, sunfish, sun perch, or panfish. Only 4 out of the 11 *Lepomis* species are extensively cultured as sport fish. They are the bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), warmouth (*Lepomis gulosus*), and green sunfish (*Lepomis cyanellus*). The bluegill is probably the most well known of all sunfish species and has been stocked throughout North America as a game fish. It is most abundant in shallow, eutrophic lakes and ponds but can also be found in streams. The redear, also known as "shellcracker" and "chinquapin," has also been stocked throughout North America as a game fish or used as a companion to bluegill in controlled systems, but it prefers sluggish waters. The warmouth, or "goggle-eye," occupies sluggish waters and is not usually used to stock recreational waters. Its main use is for the production of hybrids with other primary *Lepomis* species. Green sunfish are also known to hybridize with other *Lepomis* species. They are found in a wide range of habitats (from ponds and lakes to river systems) and are perhaps the most adaptable and abundant of all the sunfish species.

The most popular size for stocking of bluegills, redears, and sunfish hybrids is 50 mm. Bluegills and redears are stocked as forage species for largemouth bass and also for sportfishing. There has also been newfound interest in using bluegills, redears, and some sunfish hybrids in nontraditional markets such as foodfish for human consumption and use in fee-fishing operations.

The two *Pomoxis* species, the black crappie (*Pomoxis nigromaculatus*) and white crappie (*Pomoxis annularis*), are cultured for stocking ponds, lakes, and reservoirs. Black crappies are common in Quebec and Manitoba provinces in Canada, the northern and eastern portions of the United States, and as far south as Florida and Texas. White crappies are common in southern Ontario, Canada, in Minnesota and states eastward, and as far south as the Gulf of Mexico.

Production Systems

Most culture of sunfish occurs in ponds. Spawning ponds should be less than 3 ac and 2 to 5 ft deep, with a smooth, evenly sloped bottom. It is recommended that the ponds be filled at least 2 to 4 wk before spawning activity commences and that the ponds be completely free of any other fish species. A plankton bloom should also be established before the spawning activity begins. This can be accomplished through the use of organic or inorganic fertilizers. Groundwater is the preferred water source for production ponds, and the water level can be manipulated by drainpipes (Brunson and Robinette, 2000).

Culture Practices

It is critical to properly identify broodfish used for sunfish culture to ensure that the desired offspring are produced because *Lepomis* species have a tendency to hybridize. *Lepomis* broodfish spawn very soon after optimum temperatures have been reached. A powder or mash is usually the first food given, and then feed particles matched to the size of the fish are given as the fish grow. The fish are grown out to at least 2 in. before harvesting because smaller-sized fish stress easily (Brunson and Robinette, 2000).

Both *Pomoxis* species are cultured similarly. Usually, 2-yr-old crappies are put into ponds to spawn, and they are given fathead minnows, threadfin, or gizzard shad as forage. Spawning and egg incubation proceed naturally in the open ponds. After crappie eggs hatch, the fish can be transferred to small raceways to be trained to accept prepared rations or pelleted feeds. They are then harvested as fingerlings.

Care needs to be taken during harvesting because handling stress can increase the incidence of columnaris disease. It has been found that harvesting fingerlings during winter can reduce handling stress, and that black and hybrid crappies endure handling stress better than white crappies (Brunson and Robinette, 2000).

4.3.6.8 Walleye

Walleye *(Stizostedion vitreum)* are raised as foodfish and for stocking purposes. Most commercial harvest of wild walleye in North America occurs on the Canadian shore of Lake Erie and in isolated lakes of western Ontario and the Canadian Prairie Provinces. In the United States, some tribes harvest a small amount of walleye on the Great Lakes for subsistence and also commercial purposes.

Production Systems

Several types of culture systems are used, including pond culture, tandem pond-to-tank culture, pond-to-tank-to-pond culture, cage culture, and intensive culture. In any of the culture systems, walleye eat diatoms, rotifers, and copepod nauplii, cyclopoid copepods, or small soft-bodied cladocerans when the fish are young. As they grow, their diet switches to larger cladocerans and then to immature aquatic insects.

Fingerling walleye can be produced in drainable ponds, with levees on all four sides, or undrainable ponds, which include farm and ranch ponds, shallow natural lakes, marshes, borrow pit ponds, and dug ponds. Drainable ponds are prepared by seeding pond bottoms with an annual rye grass, if there is adequate time between pond drainage and the next production cycle, or drying and disking the ponds if seeding is not possible. Additions of agricultural lime ($CaCO_3$) may be necessary to increase alkalinity, and additions of caustic (hydrated) lime ($Ca(OH)_2$) may be necessary to kill parasites after pond drainage. Ponds may be filled with groundwater or surface water, but surface water must be filtered so that unwanted organisms are not introduced to the pond. There is little information on pond culture in undrainable ponds. It is known that stocking densities in undrainable ponds are much less than in drainable ponds; however, there is a wide range of stocking densities in both types of ponds.

Tandem pond-tank culture is used to grow phase II fingerlings because it is hard to raise a large number of walleye to sizes over 4 in. in ponds (unless forage fish are added). Fingerlings are transferred from ponds to indoor culture tanks after they are accustomed to formulated feed diets and are raised to a size of 5 to 8 in.

In pond-to-tank-to-pond culture, phase II fingerlings are pond-raised and overwintered. In early spring they are transferred to cages in small ponds (0.16 ac), where they are put on formulated feed diets. Feed-trained fingerlings are then returned to ponds, where they remain on the manufactured feed diet, and raised for a few years to produce food-size fish. This culture method is uneconomical because of high mortality rates in all stages of the culture process (between fry stocking and fingerling harvest, during overwintering in ponds, during transfer of fingerlings from ponds to cages and to formulated feed diets, and during transfer back to ponds and another overwintering).

Walleye can also be raised in cages tethered to piers, docks, or rafts. This culture method has been used in water-filled gravel and rock quarries, natural and artificial lakes, and farm ponds. It has been used to raise fry to fingerlings, phase I pond-raised fingerlings to phase II fingerlings for enhancement stocking, and food-size fish. The survival rate of fingerlings from summer to fall is higher if feed-trained fingerlings are used instead of trying to train pond-raised fingerlings to take commercial feed in the cages.

Intensive culture refers to raising finfish in flowing water systems, such as flow-through systems, at a high density, and it encompasses single-pass (one-use), serial-reuse (stair-step raceway), and recirculating systems. These systems use high exchange rates of water, which allows for a good supply of oxygen in the culture tank and removal of dissolved wastes such as ammonia. Intensive culture is most often used to adjust phase I fingerlings to formulated feed and then to grow them to fall fingerlings. The feed-trained fingerlings can reach a marketable food-size when raised in intensive culture. Advantages of intensive culture include raising the fish indoors under optimum conditions, raising the fish where space or water supply is limited, and acclimating fingerlings or fry to formulated feed rations under controlled conditions (Summerfelt, 2000).

Culture Practices

In drainable and undrainable ponds, fingerlings can be partially harvested by trapping or seining; however, in drainable ponds, they are most often harvested all at once by being drained into a catch basin. A distinctive characteristic of walleye fingerlings is their attraction to light, allowing for easy capture in light traps to monitor populations. After the fish cease to have an attraction to light (when they are around 1.6 in. in size), sampling can be done through nighttime seining (Summerfelt, 2000).

Culture practices for raising walleye to food-size include combinations of the above-mentioned systems. Phase I fingerlings can be raised in ponds until the fish are about 1.25 to 2.5 in. in length, at which time they must be harvested so that fish density can be determined. The phase I fingerlings need to be trained to accept formulated feed, and this can be initiated in intensive culture systems or in ponds. Ponds must be restocked at densities suitable for growth of the fish to a larger size, and then fingerlings can be raised through the end of the growing season to an average size of 5 to 8 in., when they are known as phase II fingerlings (Summerfelt, 1996). Phase II fingerlings must be overwintered in adequately aerated ponds and can reach sizes of 12 to 14 in. by the end of the second summer in southern Iowa and the middle to end of the third summer in more northern locations (Summerfelt, 1996). Disadvantages to pond culture of food-size walleye include the length of time for the fish to grow out to market size, potential winterkill, and potential summerkill in instances of prolonged high temperatures (Summerfelt, 1996).

Walleye can be raised to food-size in flow-through systems, such as raceways or circular tanks, as long as the tanks are covered to reduce intense sunlight, to which walleye are sensitive. The greatest limitation of these flow-through culture systems is the necessity for available water sources with desirable water temperature. Flow-through systems must have a plentiful supply of water in the 66 to 77 °F range because growth rates diminish to nearly zero at temperatures lower than 60 °F. Intensive culture has a much higher survival rate than ponds for growout of walleye to food-size (Summerfelt, 1996). Fry can be cultured intensively by feeding them brine shrimp or formulated feed, and then grown out to food-size. Another option is to transfer phase I fingerlings raised in ponds into intensive culture systems to be habituated to formulated feed (Summerfelt, 1996).

Recirculating systems are another choice for raising walleye to food-size. The systems can be used throughout North America, with new water use minimized to around 5% or less of the total system volume per day and fish stocked at high densities and raised on pelleted feeds (Summerfelt, 1996). Recirculating systems are advantageous because the controlled water temperature allows for a 12-mo growing season. These systems also have low water requirements relative to production capabilities, produce a small volume of concentrated waste, and offer the opportunity to locate facilities near major markets.

4.3.6.9 Yellow Perch

Yellow perch *(Perca flavescens)* is a popular food fish with high market demand. It is a coolwater species found in the Great Lakes region and Canada. Yellow perch harvests from the Great Lakes surpassed 33 million lb/yr in the 1950s and 1960s, and market demand kept up with the large supply. In the 1980s and 1990s, harvests fell to between 11 million and 17.6 million lb/yr. Commercially cultured yellow perch now add to the supply, and the market demand is high for them because of their freshness and because of concerns regarding microcontaminants in wild-caught fish (Manci, 2000).

Production Systems

Most commercial yellow perch production is conducted in ponds, but there is also potential for cage culture (KSUAP, n.d.). Ponds are prepared by adding organic fertilizer to stimulate the growth of zooplankton, which acts as a food source for newly hatched fry (Wallat and Tiu, 1999).

Culture Practices

It takes about 18 mo to grow yellow perch to a harvest size of 0.25 lb. Some research has indicated that stocking yellow perch at high densities could be advantageous to production because the high densities stimulate feeding activity and allow for maximum growth (KSUAP, n.d.).

4.3.7 Baitfish

Baitfish is the term used to describe live fish sold as fishing bait or as “feeders,” which are fish fed to ornamental fish and to invertebrates with piscivorous food habits (Stone, 2000). More than 20 species are caught in the wild and used for bait, but fewer species are raised on farms. Farmers face strong price competition from wild-caught bait, which has negatively affected the profitability of baitfish farming. If farm-raised fish cannot be supplied at a competitive price, the result is increased harvest pressures on wild stocks to meet market demands (Stone et al., n.d.). The common farm-raised species are the golden shiner (*Notemigonus crysoleucas*), the fathead minnow (*Pimephales promelas*), and the goldfish (*Carassius auratus*) (Stone, 2000). The baitfish industry is one of two non-food production sectors in U.S. AAP. (The other sector is ornamental fish production.) According to the 1998 Census of Aquaculture, the baitfish industry generated $37.5 million in total sales with 275 growers throughout the country (USDA, 2000).

According to the Census of Aquaculture, Arkansas leads the industry in production of baitfish in the United States, with 62 growers and $23 million in total sales; however, it is believed that the number of farms and the value of the industry are higher than the Census figures indicate. For example, Collins and Stone (1999) estimated the 1998 value of Arkansas baitfish production at $37.9 million. Compared to foodfish culture, baitfish culture is unique in the vast number of individual fish produced and the variety of sizes required by the market. In addition, the impact of competitive market forces plays a critical role in the baitfish industry. Demand for bait is seasonal, driven by regional customer preferences, and sensitive to weather conditions (Stone, 2000). Farmers monitor weekend weather forecasts for regions where their fish are sold to determine how many fish to harvest, grade, and harden in vats in anticipation of sales orders. For example, a warm winter means fewer days of ice fishing and a reduced market for minnows (Stone et al., n.d.)

Sources of baitfish include wild capture, extensive culture, and intensive culture. In the past, most baitfish were captured in the wild. In some areas, collecting small fish for bait is still legal, and commercial fishermen use seines or traps to harvest the fish. Farming fish for bait grew in response to shortages of wild-caught minnows in the 1930s and 1940s, as well as concerns over the possible depletion of wild stocks. Extensive culture, more common in northern states, is the practice of raising seasonal crops of fathead minnows or white suckers in shallow lakes. Fry are stocked in the spring and allowed to grow. The fish are raised on natural food alone. With this form of culture, the production yields are lower than those in intensive culture, which has a higher biomass within the production unit, but the costs incurred by the operator are also lower.

In 1934 the Michigan Department of Conservation began experimenting with minnow propagation (Stone, 2000). In the late 1940s through the 1970s, baitfish farms grew rapidly (Stone et al., 1997). Today about half of all baitfish are farm-raised (Stone, 2000). The first baitfish farms in Arkansas began in the late 1940s. In 1997 Arkansas had an estimated 27,800 ac under cultivation for baitfish (USDA, 2000). Most baitfish farm acreage produces golden shiners and fathead minnows (Stone et al., 1997). Golden shiners are the predominant species raised in Arkansas (Collins and Stone, 1999). Fathead minnows are the most common species raised in the North Central Region, which includes Illinois, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin (Meronek et al., 1997). Goldfish are primarily raised in Arkansas and the southern part of the North Central Region (Gunderson and Tucker, 2000). Golden shiners are both wild-harvested and cultured in the North Central Region, while goldfish are only cultured (Gunderson and Tucker, 2000).

The production of farm-raised baitfish can help to minimize environmental impacts by reducing the demand for wild-caught baitfish. These fish are an integral part of the food chain for freshwater systems. Their decline could impact the entire ecosystem by reducing the number of forage fish. Also, the transfer of wild-caught baitfish from their native populations to other sites across the country raises concern about possible infiltration of nonnative species.

4.3.7.1 Production Systems

Although culture practices vary with species and from farm to farm, most baitfish are raised in earthen ponds. Ponds used for golden shiners range in size from 5 to 20 ac, while ponds for fathead minnows are usually up to 10 ac (Stone, 2000). Ponds for goldfish are even smaller, with an average pond size of 2 ac. Water depth is relatively shallow, ranging from 2.5 to 6 ft to help farmers harvest fish without draining the ponds. Groundwater is used most often to fill ponds for baitfish culture. If surface water is used, farmers use fine-mesh, self-cleaning filters to prevent the introduction of wild fish into baitfish ponds. Golden shiners and fathead minnows are partially harvested from ponds during the year. Fish are baited into a corner and harvested by surrounding the fish with a seine. By the time the pond is emptied, the standing crop has been reduced to 25 to 50 lb/ac.

4.3.7.2 Culture Practices

Golden shiners and goldfish have traditionally been propagated using either the wild-spawn method or the egg-transfer method (Stone, 2000). With the wild-spawn method, broodfish are stocked into newly filled ponds with aquatic vegetation in shallow water. Fish spawn freely on the vegetation, and then juveniles are either raised with their parents or transferred to another pond. In the wild-spawn method, fry are often vulnerable to predation by older generations of fish. Although fathead minnow growers generally use the wild-spawn method, most golden shiner and goldfish farmers use the egg-transfer method. In the latter method, spawning mats are used to collect eggs, and then the eggs are transferred to a rearing pond filled with a shallow layer of fresh well water (not filled to capacity) for incubation and hatching. Eggs hatch in 3 to 7 d.

Usually, eggs or fry are stocked into prepared ponds at higher densities, and when the juvenile fish are large enough, they are spread out into other ponds at lower densities. Juvenile fish can be stocked into ponds with adult fish once they are large enough to avoid being eaten. The growing season in the North Central Region is shorter (120 to 150 d) than that in Arkansas (180 d); therefore, the size attained by golden shiners and goldfish over a single growing season in the North Central Region is smaller (Gunderson and Tucker, 2000).

In preparation for stocking fry, ponds are fertilized to encourage the development of natural food. Golden shiners feed on zooplankton, but they also eat a wide variety of other animal and plant materials (Stone, 2000). Fathead minnows are primarily algae eaters, but they also eat zooplankton and insect larvae. Young goldfish feed primarily on zooplankton; as they age, they also feed on algae and detritus.

Feeding practices vary greatly among producers. Unlike in foodfish culture, the primary goal in baitfish production is not to grow the fish to market size as fast as possible; instead, producers manipulate the stocking density and feeding rate to produce a variety of sizes (Stone et al., 1997). Feeding rates for baitfish are determined by the market demand for various fish sizes. In Arkansas many farmers start feeding at 5 lb/ac/d, then gradually increase to 10 or 15 lb/ac/d. Most of the feed input to ponds is thought to contribute to the natural production of food organisms (Stone and Park, 2001, personal communication). Many baitfish farmers feed in one area of a pond, where aerators are placed, to attract fish for ease of harvest with seines. In the northern North Central Region, golden shiners are usually not fed prepared feed (Gunderson and Tucker, 2000).

Farmers also apply fertilizer to promote the growth of natural food. As a general rule, a single application of inorganic fertilizer for baitfish ponds should contain 3 to 4 lb/ac of phosphorus (Stone et al., 1997). Organic fertilizers, such as vegetable meals, hay, and poultry litter, are normally used only for fry nursery ponds in combination with inorganic fertilizer. Fertilizer use has declined as farmers have switched to using prepared feeds, but natural food is still an important part of the baitfish diet (Stone et al., n.d.).

The biomass for baitfish in pond culture is low. Average yields for baitfish production are 350 lb/ac for golden shiners and fathead minnows, and 790 lb/ac for goldfish (Collins and Stone, 1999). In contrast, foodfish raised in ponds are stocked at approximately 6,000 lb/ac.

4.3.7.3 Water Quality Management Practices

A common practice in Arkansas is to drain and pump water from pond to pond. The most common type of drain used in baitfish production ponds is the inside swivel drain (Stone et al., 1997). The swivel drain allows baitfish farmers to drain the pond from the top of the pond (the surface of the water) and minimize the release of solids during draining.

Water is transferred when ponds are drained to conserve water and reduce pumping costs. Drains are installed to transfer water between ponds, or diesel pumps are used to pump water from pond to pond. Boyd (1990) describes a method developed to reuse water on a large minnow pond in Arkansas. The farm installed pipes at the water level of adjacent ponds. When the pond is emptied, water is pumped into adjacent ponds and stored. After the pond is harvested, the cross pipes are opened, and the pond is refilled. Baitfish farmers in Arkansas routinely capture rainwater and prevent overflow from the ponds by maintaining pond water levels at least 6 in. below the overflow pipe. When a pond is emptied, water is often captured in a ditch and then transferred to another pond for reuse.

During the spring spawning season, a number of baitfish ponds are drained to make room for the new crop of fish (Stone et al., n.d.). A pond being prepared for fry is drained to adjacent ponds. After drying to ensure that organisms that could eat the small fry will not be present, the pond is filled to a depth of about 1 ft with well water. The well water is fertilized, and as the fry grow larger, water from the adjacent ponds is transferred back. Ponds are drained sequentially, so that old water from one pond can be used to top off ponds with new fry. (During incubation and hatching, these ponds contain only a shallow layer of fresh well water.) The old water has the advantage of containing natural foods for the young fry. Generally, this is the only time of year at which any discharge reaches receiving streams (Stone et al., n.d.). The volume of discharge is typically less than the volume of the pond because of water management practices that support the transfer and reuse of pond water.

Little data is available on water quality in commercial baitfish ponds or on effluents from these ponds; however, the impact is likely to be minimal. Baitfish production uses low biomass stocking densities. Also, current management practices within the industry reduce potential impacts of effluent discharges. Farmers seine by hand to prevent stirring up sediments because small baitfish are sensitive to muddy conditions. Farmers begin with a low biomass and lower the biomass density even further with partial harvests throughout the year. The combination of low biomass and reduced feed input prior to draining makes it likely that baitfish effluents will have lower solids concentrations than effluents from catfish ponds (Stone et al., n.d.). Also, it is likely that farmers' efforts to conserve water have also reduced effluent quantities.

4.3.8 Ornamental Fish

The culture of ornamental, or tropical, fish is primarily to supply animals for the home aquarium where fish are kept as a hobby or as pets. The ornamental fish industry is one of the two major non-food production sectors in the AAP industry; the baitfish industry is the other sector. Although many freshwater ornamental species are cultured, some examples are guppies *(Lebistes reticulates*), mollies (*Mollienesia* sp.), swordtails (*Xiphophorus* sp.), tetras (*Hemigrammus* sp.), gouramis (*Osphroneums, Sphaerichthys, Trichogaser* sp.), and goldfish (*Carassius auratus auratus*). More than 1,000 freshwater species in about 100 families are represented in the ornamental fish trade at any one time; however, only about 150 species are in great demand and account for the largest volume of trade (Chapman, 2000). Most ornamental fish currently produced in the United States are freshwater fish. Nearly 80% of the freshwater ornamental fish sold in the United States are raised in confinement, and the majority of those are raised in pond operations (Stoskopf, 1993). The production of marine ornamental fish is an emerging industry with few species regularly reproduced in captivity. Some of the most common species available from marine culture facilities include the clownfish (*Amphiprion* spp. and *Premnas biaculeatus*), the neon goby (*Gobiosoma oceanops*), and the dottyback (*Psuedochromis* spp. and *Ogilbyina novaehollandiae*).

According to the 1998 Census of Aquaculture, there are 345 ornamental fish farm operations in the United States, which produce roughly $68 million in total sales (USDA, 2000). Florida, with 171 growers, dominates the domestic ornamental fish industry, with approximately $56 million in total sales, or 81% of the total sales in ornamental fish species in 1998. California, Arkansas, Indiana, and Hawaii also produce ornamental fish.

Ornamental fish culture may benefit wild ornamental populations by preventing destructive collection practices, which deplete wild populations and degrade natural habitat. The Asia Pacific region is the global center of marine diversity; it supports more species of coral and fish than any other region in the world (Holt, 2000). This region is home to 4,000 species of reef fish and more than one-third of the world's coral reefs. In this region and throughout the tropics, natural populations of coral reef fish, which make up the majority of marine ornamental species, are increasingly threatened by development, dredging, coral collecting, and the live foodfish and aquarium fish trade (Holt, 2000). Many common collection methods, which include the use of dynamite and sodium cyanide, are destructive and cause damage to coral reef habitats. Loss of habitat reduces the area available for the settlement of new fish recruits.

4.3.8.1 Production Systems

Ornamental fish farming is characterized as an extensive culture (very low biomass densities) and often has two phases of production: a hatchery phase and a growout phase. Most breeding for ornamental fish takes place in recirculating systems, while the growout phase usually occurs in ponds. In many cases, ornamental fish farms are small businesses owned and operated by a family (Chapman, 2000). Farms often use a combination of both indoor and outdoor facilities for production. Indoor areas, usually built from modified greenhouses and wooden and steel sheds, are used primarily for breeding, hatching eggs, and raising larvae or fry. The remaining indoor area is used for holding, sorting, and shipping fish. The most common outdoor facilities are earthen ponds and concrete tanks. In Hawaii, broodstock of live-bearing ornamental fish are typically held in net cages in ponds, and then the juveniles are transferred to ponds for growout (JSA, 2000b). Net cages are small floating structures that allow water to flow through while retaining the confined animals (Stickney, 2000d). They are used for raising early life stages of various species, or sometimes to hold fish in advance of spawning. In Florida, live-bearer production is typically done in ponds.

Pond Systems

Although some ornamental fish are raised in recirculating systems, most are produced in outdoor earthen ponds (Watson and Shireman, n.d.). In Florida these ponds are almost all water-table ponds in sandy loams. Because the water table is so close to the surface, ponds can be created by digging out the appropriate area and letting the pond fill with water from the water table. The water level in the pond is dependent on the existing hydrology. In many areas, during dry seasons, well water is used to supplement the water table source. A typical outdoor pond in Florida is approximately 65 to 82 ft in length, 20 to 30 ft wide, and 5 to 6 ft deep. Farmers often cover outdoor ponds and tanks with nets to protect the fish from predators, or they use plastic to provide shade and maintain water temperatures, depending on the time of year (Chapman, 2000).

A typical growout pond (approximately 2,152 ft^2) may be stocked with 10,000 to 80,000 fish from egg-laying parents or with around 200 live-bearing broodfish (Chapman, 2000). After 2 mo, the live-bearing population in the pond can reach 30,000 fish. Growout ponds for juvenile freshwater ornamental fish are prepared for stocking by draining the pond after each production cycle and washing and preparing the bottom. After washing, the ponds are disinfected with hydrated lime to ensure that all predators are eliminated from the system. Although specific to individual species, some ponds remain in production unwashed for 1 to 2 yr (Chapman, 2000). The ponds are fertilized to stimulate the growth of phytoplankton in the water. Organic fertilizers are used to sustain a release of nutrients over a longer period of time. Cottonseed meal is a common organic fertilizer used by ornamental fish producers. Inorganic fertilizers provide a short-term nutrient release and are often used to initialize phytoplankton growth. After the ponds are fertilized, they are filled with water and an algae bloom is allowed to develop to encourage the creation of a natural food source.

Recirculating Systems

Although recirculating systems are used primarily for the hatchery phase of ornamental production, producers are exploring opportunities to expand growout production, using technologies from recirculating systems (JSA, 2000b). Stocking densities are higher in recirculating systems than in ponds, approaching 15 fish/gal without oxygen injection and 58 fish/gal with oxygen injection. Water for facilities using recirculating systems is often treated internally with mechanical and biological filters (Chapman, 2000). Internal processes within recirculating systems include settling basins, baffles, screens, and upflow solids contact clarifiers to remove suspended and settleable solids. To break down organic wastes, some culturists use microbes in trickling filters and modified upflow clarifiers. To disinfect treated water, some culturists use ozone and/or ultraviolet light.

Ozone is also used to oxidize organic compounds. Fine suspended solids and other dissolved organics are stripped with dissolved air flotation or foam fractionation technology.

4.3.8.2 Culture Practices

With the exception of a few species like koi and goldfish, most ornamental fish are native to tropical regions of the world and cannot tolerate temperatures below 64 °F. Ornamental fish are relatively small in size, with a market weight between 0.1 and 1.4 oz and length between 0.8 and 6 in. Aquarium fish usually live from 6 to 10 yr; however, some koi have been recorded as living as long as 70 to 80 yr (Chapman, 2000).

Based on their reproductive cycles, freshwater ornamental fish are divided into egg layers and live-bearers. Egg-laying fish deposit their eggs on spawning mats or broadcast them for external fertilization. Live-bearing fish, such as guppies, release fully developed young that are ready to feed on their own.

Most egg layers are artificially bred in indoor hatcheries. Broodfish are paired in tanks or spawned together in large groups (Chapman, 2000). Fish are stimulated into breeding by using spawning mats and by manipulating the temperature, flow, pH, and hardness of the water. Culturists sometimes use hormones like human chorionic gonadotropin or carp pituitary extract, which are injected into individual fish to induce spawning. After spawning the eggs either are allowed to hatch where they are laid or are collected and placed in incubators. The larvae that hatch are pooled and transferred to rearing tanks or outdoor ponds. The fertilization and spawning of live-bearing fish is allowed to occur naturally in breeding ponds or tanks. In production, live-bearing parents are usually separated from their offspring to prevent cannibalism.

Many of the more popular and expensive marine ornamental fish, such as butterfly fish, angelfish, and wrasses, are difficult to raise in captivity. Clownfish, neon gobies, and dottybacks are easier to raise because they can change sex; therefore, a spawning pair is not needed. Clownfish have eggs that take several days to hatch, and they produce larvae that are large enough to feed on rotifers when they hatch. In captivity, gobies spawn regularly every 2 to 3 wk and produce large eggs. Young can be raised on rotifers and zooplankton and, later, brine shrimp nauplii. Like gobies, dottybacks produce large larvae that grow quickly.

In general, it takes 3 to 6 mo to produce market-ready fish. The typical survival rate for freshwater ornamental fish in a pond is 40% to 70%. Most losses in outdoor culture systems are due to predation, deterioration of water quality, and disease. Fish are harvested with fine seine nets, dip nets, and traps (Chapman, 2000). The process for harvesting ornamental fish differs from that for foodfish because the fish are individually selected and must be kept alive. Ornamental fish are sorted by hand, based on color and size. Mechanical graders are not yet available for the ornamental industry.

Feed Management

There is very little published information on the nutrition and feeding of ornamental fish. Most dietary knowledge has evolved from trial-and-error tests by individual farmers and a few studies in research laboratories (Chapman, 2000). Although most producers rely on a natural food sources for fish in outdoor ponds, these sources are sometimes supplemented with formulated feed. Fish raised in indoor tanks are fed commercial feed mixtures. Feed is delivered by hand or automatic feeder. Because of the small particle size of the feed and the low volume of feed used for the growout phase, feed is often allotted at a constant rate of 3% to 10% of fish biomass per day for freshwater ornamental fish (Chapman, 2000). Because the biomass for ornamental fish production is small, the feed input is also small.

Health Management

Parasites and bacteria are the two most common causes of infectious diseases in ornamental fish. The most common external parasites are ciliated protozoans, primarily *Ichthyophthirius multifiliis*, or "ich," and *Trichodina.* Common treatments for external parasites include salt, formalin, copper sulfate, and potassium permanganate. The most prevalent infectious bacteria are in the aeromonad and columnaris groups. Common drugs used to treat bacterial infections are tetracycline, erythromycin, mitrofurazones, nalidixic acid, potassium permanganate, and copper sulfate (Chapman, 2000). Drugs and chemicals are not often used in pond systems because of the high cost to treat a large volume of water. Drugs or chemicals applied for ornamental culture are more commonly used in tanks for indoor recirculating systems (Watson, 2002, personal communication).

4.3.8.3 Water Management Practices

While there is little data in the literature on ornamental fish farm effluent characteristics, the impact from water discharged from ornamental fish production facilities is likely to be minimal. Assuming the average size of a growout pond is 2,152 ft^2, with approximately 80,000 gal of water, ornamental culture facilities typically discharge the volume of one pond, or less, per year (Watson, 2002, personal communication). Also, ornamental fish are extremely sensitive to water quality; therefore, water quality in the production system is constantly monitored by producers. Many producers are already implementing BMPs to reduce the impacts of effluents. For example, when ponds are drained, some facilities discharge water into settling basins, while others discharge into channels and ditches that run into surface waters. In Florida, ornamental fish farm effluents are regulated by the Florida Department of Agriculture and Consumer Services. The producer agrees to adhere to a set of BMPs, most of which deal with treatment of effluent prior to discharge (JSA, 2000b). When in compliance with Florida's BMP program, ornamental fish producers are issued an aquaculture certificate to verify their compliance. This program has a high compliance rate, estimated at 95% of the ornamental fish producers in Florida (Watson, 2002, personal communication). Because consumers and distributors often choose to buy fish only from certified aquaculture facilities, the demands of the market reinforce compliance with the BMP program.

4.3.9 Shrimp

Most commercial shrimp farms in the United States produce Pacific white shrimp (*Penaeus vannamei*), which were introduced from the Pacific coast of Central and South America, for a single annual crop (Iverson et al., 1993). According to the 1998 Census of Aquaculture (USDA, 2000), Texas is the leading producer of cultured shrimp in the United States, producing 3.7 million lb a year with a value of $9.3 million. Hawaii, with 12 farms, produced 197,000 lb with a value of $1.7 million. South Carolina, with six farms, produced approximately 43,000 lb of shrimp annually. Overall, there are 42 shrimp farms in the United States that produce a total of 4.2 million lb/yr and generate sales of $11.6 million. Blue shrimp *(P. stylirostris*) from the Pacific coast of Central and South America and giant tiger prawn (*P. monodon*) from the western Pacific have also been introduced into the United States for shrimp farming.

4.3.9.1 Production Systems

Although shrimp can be raised in tanks, raceways, or ponds, most commercial facilities raise shrimp in levee ponds. Penaeid shrimp ponds rely on access to supplies of seawater. In general, shrimp farming in the United States takes place in coastal areas, primarily along estuary systems or waterways, such as tidal rivers or canals. A facility must be able to obtain seawater from the ocean, adjacent estuaries, or a reservoir. Pumping systems are used to transfer water to the ponds, and some facilities maintain reservoirs with supplemental supplies of seawater. Shrimp ponds usually have water gate inlets and outlets to fill and drain the pond. The gates are covered with screens to keep out unwanted predators and to prevent the escape of nonnative cultured species to the receiving waters.

4.3.9.2 Culture Practices

In the wild, shrimp mate in the ocean. A single female can spawn 100,000 eggs or more at a time (Boyd and Clay, 1998). Within 24 hours of fertilization, the eggs hatch into larvae and begin feeding on plankton. The nauplius is the first larval stage. After approximately 12 days, the larval period ends and the young shrimp, now postlarvae, are carried on currents from the open ocean into nutrient-rich bays and estuaries. There they transform from organisms suspended in the water column into bottom-dwelling animals. Maturation from postlarvae to juveniles generally takes 4 to 5 mo (Treece, 2000). In the late juvenile or early adult stage, the shrimp return to the ocean to mature and mate.

Culture for marine shrimp has three phrases—hatchery, nursery, and pond growout. Many shrimp producers rely on hatcheries that specialize in the production of postlarvae or juveniles for supplies of animals to stock their growout ponds. Shrimp hatcheries require relatively small tracts of land compared to growout facilities (Treece, 2000). Broodstock shrimp are harvested from the ocean and brought to the hatchery for sexual maturation and reproduction. Mated females harvested from the wild are allowed to spawn in a nauplii production facility. Some hatcheries prefer to control all production inputs; therefore, they harvest both males and females from wild stocks and quarantine them to ensure they are free of disease and other pathogens. The most important parameters for successful maturation of penaeid shrimp are constant temperature and acceptable levels of salinity, pH, light, and nutrition. Hatcheries rely on a readily available supply of high-quality seawater for successful shrimp maturation.

Shrimp are stocked in hatchery tanks at densities of 5 to 7 shrimp/10 ft^2. The tanks are about 13 ft in diameter and are supplied with water through a flow-through system or a recirculating system (Treece, 2000). Most hatcheries now recirculate roughly 80% of the water to maintain better control over water quality (Treece, 2000). Once hatched, the young larvae (nauplii) are disinfected and evaluated for physical attributes. Nauplii with suitable physical characteristics are transferred to larval rearing tanks and stocked at densities ranging from 379 to 568 nauplii/gal (Treece, 2000). At the postlarvae stage, shrimp are transferred from the larval rearing tank to a postlarvae-rearing/holding tank. Once the postlarvae have reached the PL8-18 stage (8 to 18 d old), they are usually sold to production farms for growout. Nursery ponds are smaller ponds used for an intermediate growout phase and to eliminate substandard juveniles. Not all farms use the nursery phase. Many farms stock postlarvae, either from the wild or from the hatchery, directly into growout ponds.

Climate plays an important role in shrimp production in the United States. Compared to tropical locations, the cooler climate in the continental United States limits outdoor shrimp culture to 9 mo in southern regions of the country. Growout ponds are stocked in the early spring. Based on the characteristics of a typical facility from a 1998 report prepared for EPA, growout ponds are usually stocked at densities of 50,000 to 75,000 postlarvae/ac. Adult shrimp are harvested in the fall (September through November) approximately 140 to 170 d after stocking (SAIC, 1998). Shrimp are usually harvested by draining the pond and collecting the shrimp in bags or containers on the outside of the pond at the end of the drainpipe. Shrimp can also be harvested by pumps that draw the shrimp out of the pond with a vacuum suction. Growout ponds remain dry throughout the winter. Most shrimp farmers manage bottom sediments by allowing the ponds to dry naturally, then mechanically tilling the pond bottoms.

Feed Management

In early spring growout ponds are filled with water from a nearby estuary. Inorganic fertilizer is added to the ponds to promote plankton growth. Postlarval shrimp feed on plankton and a commercial feed supplement for several weeks after stocking. Four to six weeks after stocking, the shrimp are large enough to receive pelleted feed. The shrimp are fed by broadcasting feed into the ponds with mechanical feeders. To prevent overfeeding, most marine shrimp farmers feed at least twice a day and use feeding trays to monitor consumption. Feed placed on the feeding trays is visually inspected ½ to 1 h after being placed in the ponds to evaluate feed use. Feeding rates and quantity are determined by visual water quality, feeding tray assessments, and percent body weight increase (SAIC, 1998).

Health Management

Viruses frequently cause high mortalities in shrimp crops and limit shrimp farming production. More than 20 known viruses are associated with penaeid shrimp culture; however, only 4 of these pose a serious threat to the shrimp culture industry (Treece, 2000). The four disease-causing viruses that affect marine shrimp culture are infectious hypodermal and hematopoietic necrosis (IHHN) virus, taura syndrome virus (TSV), white spot syndrome virus (WSSV), and yellow head virus (YHV).

There are several theories on possible sources for shrimp viruses. These include entry to the facility through contaminated feed, infected broodstock or seed, and bird or animal transport. Two other potential sources are carrier organisms in ship ballast water and frozen seafood products (Browdy and Holland, 1998). Current treatment options for shrimp diseases are similar to traditional livestock disease treatment methods. Shrimp diseases are not harmful to humans due to the freezing and cooking processes typically conducted prior to consumption (Iverson et al., 1993). Facilities that do have an outbreak of disease dispose of the contaminated stock and water, and then sanitize the pond facilities. Ponds are chlorinated, dechlorinated, quarantined, and inspected before reuse (SAIC, 1998). Many shrimp facilities buy specific pathogen-free (SPF) or specific pathogen-resistant (SPR) shrimp to reduce disease outbreaks. Shrimp hatcheries are developing a new strain of *P. stylirostris* that is resistant to TSV and WSSV.

In addition to concern for the health of cultured species, there is concern for wild native populations, which can be infected by viruses carried out of an AAP facility through the discharge of pond effluent, processing plant wastewater, pond flooding, the escapement of cultured species, and the use of infected bait shrimp (SAIC, 1998). The spread of shrimp viruses is one of the most important problems limiting shrimp culture production worldwide (Browdy and Bratvold, 1998). Control of disease will depend on the development of biosecure production systems, which prevent pathogen transfer and establishment. Researchers at the Waddell Mariculture Center in South Carolina are exploring ways to create biosecure systems by identifying paths of pathogen transfer and evaluating existing technologies.

4.3.9.3 Water Quality Management

Shrimp farmers use aeration, water exchange, management of stocking densities, and feed management to improve water quality and support healthy stocks of shrimp. Shrimp production ponds are aerated to maintain sufficient levels of dissolved oxygen and to keep the water column well mixed. Shrimp farmers typically use more aeration per acre than finfish farmers because shrimp farmers must maintain sufficient oxygen levels on the pond bottom where the shrimp live. Good pond aeration also encourages natural processes within the pond to assimilate nutrients and wastes and to reduce total pollutant loads to receiving waters when pond water is discharged (Boyd, 2000).

After the shrimp are harvested in the fall, the ponds are drained and left to dry. This oxidizes the organic matter and reduces the likelihood of disease problems from growing season to growing season. Most shrimp facilities use surface water as a source and screen the inlets to prevent predators from entering the ponds. Because many of the shrimp grown in the United States are nonnative species, escapement and disease are concerns for regulatory agencies. Outlets are screened to prevent escapement. Water is often reused by draining it into closed ditches, allowing sediments to settle, and then moving the water back into the ponds from the ditches.

In the past, water use in shrimp pond production was high, with average water exchange rates ranging from 8% to 23% of the pond volume per day to flush the pond system (Hopkins et al., 1993).

In a 1991 study, Hopkins et al. compared the effect of a typical exchange rate of 14% of the pond volume per day to the effect of a lower exchange rate of 4% on the growth and survival of *P. vannamei* stocked at 76 animals/m^2 and found no difference in productivity (Table 4.3-9) (Hopkins et al., 1991). Hopkins et al. (1993) studied the effects of high water exchange at 25% and low water exchange at 2.5% on ponds stocked with *P. setiferus* at 4.1 postlarvae/ft^2. Nutrient concentrations were higher in the pond with the lower exchange rate, but the total mass of pollutants discharged was lower. Growth and survival were good under both exchange conditions, with a higher production in the pond with the reduced exchange.

Table 4.3-9. Water Quality of Inlet Water and Various Water Exchanges (Mean Values) of Shrimp Stocked at a Density of 4.1/ft²

Water Exchange Treatment	*Mean Size (lb)*	*Survival (%)*	*TSS (mg/L)*	*BOD (mg/L)*	*DO (mg/L)*	*Organic Solids (mg/L)*
Inlet water	N/A	N/A	178.9	1.5	N/A	132.2
Normal exchange (25% per day)	0.035	81.9	183.3	8.5	5.4	122.5
Reduced exchange (2.5% per day)	0.040	79.5	196.2	14.7	5.0	115.4
No exchange (0% per day)	0.041	0.2	157.3	18.8	4.8	85.3

Source: Hopkins et al., 1991.

Currently, shrimp farmers rely on lower water exchange rates. Aeration is preferred over water exchange to enhance dissolved oxygen levels (Browdy et al., 1996). In the early 1990s Texas shrimp farms, under the requirements of more strict water quality and discharge regulations, initiated a shift in water use practices. Using semiclosed systems, farmers began reusing and recirculating water within the facility. In 1998, one Texas farm, Arroyo Aquaculture Association (AAA), produced more than 1.4 million lb of shrimp on 345 ac, or approximately 4,000 lb/ac, in a semiclosed system (Treece, 2000). The farm decreased its water use from 4,500 gal/lb of shrimp produced in 1994 to 300 gal/lb of shrimp produced in 1998 through 2000. Most of the water added is used to fill ponds and offset evaporation.

Shrimp farmers like AAA have also decreased their stocking densities and increased aeration to promote optimum conditions for shrimp production. AAA decreased its stocking density from 4.7 shrimp/ft^2 to 3.3 shrimp/ft^2 and increased its aeration from 8 hp/ac to10 hp/ac (Fish Farming News, 2000). Research and industry practices have demonstrated that water exchange rates can be reduced without affecting shrimp production as long as dissolved oxygen levels are maintained.

4.3.9.4 Effluent Characteristics and Treatment Practices

The composition of pond effluents during water exchange, overflow after heavy rains, and initial stages of pond draining is similar to that of catfish pond water (Boyd and Tucker, 1998). Marine shrimp AAP facilities have two types of discharges: routine water exchange and water drained during harvest.

Shrimp pond effluents can have high concentrations of nutrients and suspended solids, high biochemical oxygen demand (BOD), and low levels of dissolved oxygen. When discharged into receiving waters, effluents with high levels of suspended solids can cause turbidity, which can reduce light available for photosynthesis. Low dissolved oxygen levels can affect estuarine organisms in the receiving waters, and excessive nutrients can accelerate plankton growth, resulting in die-offs and increased BOD in receiving waters.

There is some evidence to suggest that effluent characteristics for marine shrimp ponds are similar to effluent characteristics for catfish farms (Boyd and Tucker, 1998). For example, as stocking densities increase, the quality of effluents deteriorates. In a study by

Dierberg and Kiattisimkul (1996), data presented (Table 4.3-10) show average concentrations of water quality variables in effluent from shrimp (*P. monodon*) stocked at different rates. The quality of effluent declines for stocking densities above 3.7 shrimp/ft.

When shrimp ponds are drained, the effluent is almost identical in composition to pond water until about 80% of the pond volume has been released (Boyd, 2000). During the draining of the final 20% of the pond volume, concentrations of 5-day biochemical oxygen demand (BOD_5), TSS, and other substances increase because of sediment resuspension caused by harvest activities, crowding of agitated shrimp, and shallow and rapidly flowing water. The average BOD_5 and TSS concentrations often are about 50 mg/L and 1,000 mg/L, respectively (Boyd, 2000). The draining effluent contributes more to potential pollution than water exchange at 2%. Settling basins offer a treatment method for effluent released during shrimp harvest, especially for the highly concentrated final 20%. Settling basins or ponds remove coarse solids and the BOD_5 associated with them. Studies have shown that 60% to 80% of TSS and 15% to 30% of BOD_5 can be removed in a settling basin with only 6 to 8 h of holding time (Teichert-Coddington et al., 1999). Settling basins also reduce TSS levels.

Table 4.3-10. Composition of Discharge Waters from Ponds Stocked at Different Densities of *Penaeus Monodon*

Variable	*Stocking Density (shrimp/ft^2)*				
	2.8	***3.7***	***4.6***	***5.7***	***6.5***
Nitrite-nitrogen (mg/L)	0.02	0.01	0.06	0.08	0.08
Nitrate-nitrogen (mg/L)	0.07	0.06	0.15	0.15	0.15
Total ammonia nitrogen (mg/L)	0.98	0.98	6.36	7.87	6.50
Total nitrogen (mg/L)	3.55	4.04	14.9	20.9	17.1
Total phosphorus (mg/L)	0.18	0.25	0.53	0.49	0.32
Biochemical oxygen demand (mg/L)	10.0	11.4	28.9	33.9	28.8
Total suspended solids (mg/L)	92	114	461	797	498
Chlorophyll a (μg/L)	70	110	350	460	350

Source: Dierberg and Kiattisimkul, 1996.

Based on the 1998 report for EPA, settling ponds are the method of water treatment most commonly used by shrimp facilities discharging effluent (SAIC, 1998). Based on the facilities monitored, some commercial farms discharge as much as 600 million gallons/year (MGY), while others report zero discharges. One facility has a 20-ac settling area where discharged pond water remains for 2 d before being discharged into receiving waters. Another facility uses weirs to allow discharged water to drop 10 ft before entering a drainage ditch. Many drainage ditches are designed as settling basins to trap solids from effluent discharged from ponds.

In addition to reusing water during production in a closed ditch system, AAA uses drainage ditches equipped with aerators to serve as settling basins for water discharged during harvest. This facility also uses weirs so that the water discharged drops 10 ft into the drainage ditch, helping to promote natural aeration and mixing. Drainage ditches are periodically monitored to ensure that the BOD levels are in compliance with the state standard 6 mg/L. Arroyo also uses screens on its effluent pipes to capture foam and prevent its transfer to receiving waters. Also, water drained from the ponds during the yearly harvest is collected and allowed to settle in empty ponds for 15 d before being released into the drainage ditches.

The Southern Star facility (Texas) has a constructed wetland area that is used to treat effluent from shrimp ponds. The wetland was constructed by building a dike around 100 ac of previously unused land adjacent to the facility. The wetland is designed to treat discharged wastewater and then filter recirculated water back to the ponds for reuse (SAIC, 1998).

Harlingen Shrimp Farms, located in Texas, is one of the largest shrimp farming operations in the United States. Pond effluent is usually discharged through water exchanges that begin 30 days after stocking the ponds, and all growout ponds are drained for harvesting 140 to 170 d after stocking. Routine water exchange rates of 10% to 20% occur until dissolved oxygen level fluctuations stabilize. Each pond is equipped with six to fifteen 8-in. pipes and one 35-in. gate for draining water during harvest (SAIC, 1998).

4.3.9.5 Freshwater Prawn

The Malaysian prawn (*Macrobrachium rosenbergii*), a freshwater prawn, has been cultured on a limited scale in the United States (KSU, 2002). The primary economic challenges associated with culturing shrimp in the United States are the availability of low-cost, high-quality feed; shorter growing seasons, with only one crop per year in some areas due to temperatures; the high cost of land and labor; high operating costs; foreign competition; and price fluctuations (Treece, 2000).

The Malaysian prawn spends part of its natural life cycle in saltwater. Adult shrimp migrate down rivers to estuaries to have their young. The prawns spend their early larval lives in brackish water, migrating to freshwater as juveniles and remaining there as adults (Iverson et. al., 1993). The larvae feed by sight on zooplankton, worms, and larval stages of other aquatic invertebrates. Larvae undergo 11 molts before transforming into postlarvae. Transformation from newly hatched larvae to postlarvae requires 15 to 40 d, depending on food quality and quantity and temperature. After their metamorphosis to postlarvae, prawns change from living suspended in the water column to dwelling principally near the bottom (D'Abramo and Brunson, 1996a). Postlarvae can tolerate a range of salinities. They migrate to freshwater upon transformation, where they take on a bluish to brownish color as they change to the juvenile stage. Postlarvae are juveniles, but the common usage for the term *juvenile* is to describe freshwater prawns between postlarva and adult (D'Abramo and Brunson, 1996a).

Production Systems

As in penaeid shrimp production, most freshwater shrimp culture facilities use earthen ponds to produce shrimp. Ponds used for raising freshwater prawns have many of the same features as ponds used for the culture of channel catfish. Surface areas for growout ponds range from 1 to 5 ac, but some producers use larger ponds. Ponds are usually rectangular with a minimum depth of 2 to 3 ft at the shallow end and a maximum depth of 3.5 to 5 ft at the deep end (D'Abramo and Brunson, 1996b).

Culture Practices

As in penaeid shrimp culture, there are three phases of culture for freshwater prawns—hatchery, nursery, and pond growout. Many prawn producers purchase juveniles for the pond growout phase. Commercial hatcheries in Texas, California, and Mexico produce postlarvae and juveniles (D'Abramo and Brunson, 1996b).

Ponds are filled and then fertilized to provide natural food for the prawns and to create a phytoplankton bloom to shade out unwanted bottom plants. Juveniles are usually stocked at densities of 12,000 to 16,000 per acre. The length of the growout period depends on the water temperature of the ponds, but it is generally 120 to 180 d in the southern United States (D'Abramo and Brunson, 1996b). At the end of the growout season, prawns are harvested by seine or by draining the pond. For seining, the water volume is decreased by one-half before seining. During drain-down harvests, prawns are usually collected outside the pond levee as they travel through a drainpipe to a collecting device (D'Abramo and Brunson, 1996b). Some producers selectively harvest large prawns 4 to 6 wk before the final harvest. After the harvest prawns are chilled and then marketed fresh on ice. They may be processed and frozen, or frozen whole for storage and shipment.

Feed Management

Juveniles stocked in growout ponds initially feed on natural pond organisms. As the juveniles grow to a weight of 0.011 lb or greater, prawns are fed a manufactured feed. Channel catfish feed with 28% to 32% crude protein can be used for prawns. The feeding rate is determined by the mean weight of the population.

Health Management

Diseases do not appear to be a significant problem in freshwater prawn culture; however, as densities are increased, diseases are likely to be more prevalent (D'Abramo and Brunson, 1996b). Blackspot disease, also called shell disease, could affect freshwater shrimp. This disease is caused by bacteria that break down the outer skeleton.

Water Characteristics and Effluent Treatment Practices

Like catfish ponds, freshwater prawn ponds use aerators to maintain adequate dissolved oxygen levels and prevent thermal stratification. Farmers monitor dissolved levels in the bottom 1 ft of the pond water to make sure that dissolved oxygen concentrations do not fall below 3 ppm. A common method in freshwater prawn culture is the use of full-time or nightly aeration. Farmers typically use 1 hp/ac (D'Abramo and Brunson, 1996b). Because standing crops rarely exceed 1,000 lb/ac, this level of aeration is usually sufficient to prevent oxygen depletion. Some farmers use only emergency aeration as needed. Unlike marine shrimp production, there is no water exchange for freshwater prawn production. Nutrients in the pond are partially assimilated by pond processes (Boyd and Tucker, 1998).

There is very little data available in the literature describing the characteristics of effluent from freshwater shrimp ponds or effluent management practices associated with these ponds.

4.3.10 Crawfish

Red swamp crawfish (*Procambarus clarkii*) and white river crawfish (*Procambarus acutus acutus*) account for about 90% of all crawfish cultured in the United States (Davis, n.d.). Currently, crawfish represent the only crustacean species cultured on a large-scale basis in the United States (USDA, 1995). As a commercially available food source, crawfish can be traced back to New Orleans French Market records from the 1800s (LSU, 1999). A commercial fishery for wild crawfish was developed in the 1940s in the Atchafalaya River swamp in Louisiana, where crawfish are still harvested today. Because catches from the wild were unpredictable and driven by seasonal changes, an increase in consumer demand for a year-round supply eventually led to the development of a crawfish AAP industry in Louisiana (de la Bretonne and Romaire, 1990b).

In 1993 more than 59.5 million lb of crawfish with a value of $26.7 million were produced in Louisiana on more than 143,000 ac of ponds operated by 1,618 producers (USDA, 1995). Production in Louisiana represents over 90% of the total U.S. farmed production for crawfish, 70% of which is consumed locally (de la Bretonne and Romaire, 1990a). In addition to Louisiana, some 21,000 acres of ponds are used for culturing crawfish in Texas; Mississippi, Maryland, South Carolina, North Carolina, Florida, Georgia, and California also have commercial crawfish farms. There are also some smaller producers in the midwestern and northeastern United States that culture crawfish for fish bait (Eversole and McClain, 2000).

4.3.10.1 Production Systems

Culture methods used to grow crawfish complement farm management plans by using marginal agricultural land, permanent farm labor, and farm equipment in the off-peak agricultural farming periods (de la Bretonne and Romaire, 1990b). There are two types of crawfish ponds: permanent ponds and rotational ponds (LSU, 1999). Permanent ponds are ponds that remain in the same location and have a continuous management plan applied year after year. Rotational ponds describe the practice of rotating the annual sequence of crops grown in a pond or rotating the physical location of the field in which crawfish are grown.

Permanent Ponds

Approximately half of the ponds in Louisiana are classified as permanent ponds (LSU, 1999). The three primary types of permanent ponds are single-crop crawfish ponds, naturally vegetated ponds, and wooded ponds. The typical culture cycle for permanent ponds is as follows (LSU, 1999):

Time	Procedure
April–May	Stock 50 to 60 lb of adult crawfish per acre (new ponds only)
May–June	Drain pond over a 2- to 4-wk period
June–August	Plant crawfish forage or manage natural vegetation
October	Reflood pond
November–May/June	Harvest crawfish
May/June	Drain pond and repeat cycle without restocking crawfish

Single-crop crawfish ponds are managed solely for the purpose of cultivating crawfish. Crawfish can be harvested 1 or 2 mo longer because there is no overlap with planting, draining, or harvesting schedules for other crops. Naturally vegetated ponds usually refer to marsh impoundments and agricultural lands that are managed to encourage the growth of naturally occurring vegetation as a forage base for crawfish. High amounts of organic matter in the soil often lower the water quality, which decreases production. Though marsh ponds exist in Louisiana, they are not usually recommended for commercial production because of inconsistent yields. The last type of permanent pond is a wooded pond. Wooded ponds are built on heavy clay soils in forested areas (cypress-tupelo swamps) near drainage canals. Leaf litter provides the bulk of forage, but water quality is difficult to manage. While wooded ponds may provide advantages such as potential for waterfowl hunting, low initial start-up costs, and selective removal of unwanted vegetation, overall production per acre is usually lower than that for other management regimes (LSU, 1999).

Rotational Ponds

The most common crawfish-agronomic crop rotations are rice-crawfish-rice; rice-crawfish-soybeans; rice-crawfish-fallow; and field rotation. In rice-crawfish-rice rotations, rice and crawfish are double-cropped annually. A rice farmer can use the same land, equipment, pumps, and farm labor that are already in place. Farmers plant rice in a drained field (a shallow pond with a depth of roughly 18 in.) and then flood the field 6 to 8 wk later. After the field has been flooded, crawfish are stocked to grow and reproduce. When the fields are drained in August to harvest the rice, crawfish burrow underground. Crawfish burrow when water temperatures become too warm and when oxygen levels are low. They can survive as long as their gills stay moist. After the grain is harvested, the remaining stubble is fertilized, flooded, and allowed to regrow (ratoon) (LSU, 1999). The ratoon crop is used as a forage base for crawfish. Crawfish are harvested between November and April; however, the harvest season is shortened in rotational ponds because ponds are usually drained in March or April to prepare fields to replant rice in the spring. Crawfish are harvested using baited traps. Harvesting crawfish is labor-intensive and accounts for nearly two-thirds of the production costs (LSU, 1999).

The following is a typical rotation schedule for rice-crawfish-rice rotations (LSU, 1999):

Time	Procedure
March–April	Plant rice
June	At permanent flood (rice 8 to 10 in. high), stock 50 to 60 lb of adult crawfish per acre
August	Drain pond and harvest rice (later in northern Louisiana)
October	Reflood rice fields
November–April	Harvest crawfish
March–April	Drain pond and replant rice

In rice-crawfish-soybeans rotations, three crops are produced in 2 yr. This rotation has the advantage of allowing for a longer crawfish harvest season than the rice-crawfish-rice rotation. The rice-crawfish-fallow rotation allows the farmer to leave the land fallow for a certain period of time to break the natural cycle of certain weeds and prevent overpopulation of crawfish. This is a common practice in southwest Louisiana. After several years in production, rotational ponds may develop stunted crawfish as a result of overpopulation in the pond. Some farmers relocate crawfish in stunted ponds by moving mature crawfish from the affected pond to stock a new pond that will be used in a crawfish-agronomic rotation. The affected pond is left dry during the part of the cycle during which crawfish would be harvested (LSU, 1999). When crawfish are produced with other crops through the rotational crop system, producers use the same amount of water they would need if they were raising only crawfish.

Health Management

Crawfish are sensitive to most chemicals. Four herbicides are approved for use in rice or soybean fields intended for use as crawfish ponds: Stam, Basagran, 2,4-D and Rodeo (LSU, 1999). The use of herbicides to control weeds is a common management tool for rice and soybean crop production. Farmers use broad-spectrum herbicides like 2,4-D as a pre-emergent treatment prior to planting rice to kill any native vegetation (weeds). Narrow spectrum herbicides like Rodeo are used to spot-treat post-emergent weeds. The mixture of herbicides, both broad-spectrum and narrow-spectrum, used to support rice and soybean growth is independent from crawfish production.

Of all insecticides available, only Malathion and Bt are labeled for use in crawfish ponds. Malathion is commonly used to control mosquitoes. There are no plant fungicides labeled for use in crawfish ponds or in fields intended for use as crawfish ponds. The frequency with which herbicides are used is unknown. Considering the potential to eliminate the crawfish crop plus the added expense of the chemicals, it is not likely that herbicides are used often; therefore, the impact on water quality would be negligible. If herbicides are used, farmers use them in association with their agricultural crops and use them sparingly to avoid building up chemical toxicities that could adversely affect crawfish.

Primary disease pathogens of crawfish include bacteria, fungi, protozoans, and parasitic worms; however, disease problems associated with current crawfish culture practices have been minor (LSU, 1999). In estimating variable costs of crawfish production for a 40-ac pond in southwestern Louisiana, herbicides are listed as a potential expense, but drugs to treat diseases are not included in the report (de la Bretonne and Romaire, 1990a). Using drugs to treat crawfish ponds for disease is not likely to be a common practice; however, if a disease outbreak does occur, this might result in a reduced crawfish crop for the season.

4.3.10.2 Effluent Characteristics

In a study conducted by the Southern Regional Aquaculture Center (Tucker, 1998) to characterize the quality of effluents from commercial crawfish ponds, samples were collected from 17 commercial ponds in south-central and southwest Louisiana. Three types of culture systems were selected: crawfish- rice field (rotational), single-crop crawfish (permanent), and wooded (permanent). Rice-field ponds included rice-crawfish double-cropping systems. Permanent crawfish ponds selected either were planted with rice or sorghum-sudan grass in early to late summer or were not planted with cultivated forages and had native aquatic and terrestrial plants.

Dissolved oxygen concentrations in crawfish pond effluents ranged from 0.4 to 12.6 mg/L. The concentration in effluent in fall (mean = 6.5 mg/L) was higher than the concentration in winter (mean = 4.7 mg/L), spring (mean = 4.9 mg/L), and summer (mean = 4.3 mg/L). Ponds with native vegetation had the lowest concentration of dissolved oxygen in effluents (mean = less than 3.5 mg/L) because relatively high quantities of vegetative biomass depleted oxygen in the ponds.

Total solids concentration in the spring and summer ranged from 143 mg/L to 2,431 mg/L (mean = 522 mg/L), and total volatile solids ranged from 0 mg/L to 432 mg/L (mean = 96 mg/L). Effluents from ponds with native vegetation had significantly lower concentrations of total solids and total volatile solids in spring and summer (mean = 286 mg/L and 69 mg/L, respectively) than in rice ponds (mean = 646 mg/L and 113 mg/L) and sorgham-sudan grass ponds (mean = 578 mg/L and 92 mg/L). Soluble reactive phosphorus concentrations ranged from 0.002 to 0.653 mg/L (mean + 0.116 mg/L), and total phosphorus concentrations ranged from 0.039 mg/L to 1.126 mg/L (mean = 0.329 mg/L).

Results from the study showed that concentrations of nutrients and solids in effluents in crawfish ponds were generally higher in the spring and summer. Effluent quality was poorest during the summer drainage period. The type and quantity of summer vegetation had a significant influence on the quality of water discharged from crawfish ponds. Ponds with native vegetation generally had lower concentrations of nutrients and solids than ponds with rice or sorghum-sudan grass. The presence of aquatic macrophytes in spring and summer in ponds with native vegetation increased nutrient uptake and reduced the level of suspended sediments. This study suggests that ponds with native vegetation are more likely to have better water quality.

4.3.10.3 Current Effluent Treatment Practices Within the Industry

As in other ponds systems, the most important water quality concern in crawfish ponds is the level of dissolved oxygen. Dissolved oxygen should be maintained above 3 mg/L for optimal crawfish production (LSU, 1999). Problems with dissolved oxygen in crawfish AAP are compounded by the presence of large amounts of decomposing vegetation, which make typical remedies like emergency aerators ineffective (Eversole and McClain, 2000). Instead, crawfish farmers rely on preventive management measures such as the choice of forage type, the timing of flooding dates, the close monitoring of water quality conditions, and pond designs that divert flow to all areas of the pond. To improve levels of dissolved oxygen, some crawfish farmers use paddlewheel aerators coupled with diversion levees in the pond to improve circulation and maintain adequate dissolved oxygen levels (Eversole and McClain, 2000). Whereas feed management and the impacts of adding pelleted feed to the system are usually important water quality considerations for the culture of other species, feeding is not a regular practice in crawfish culture (Eversole and McClain, 2000). Instead, current production practices rely on a forage-based system. There are no feed management practices to recommend for this subcategory because the feed input is low and additional feed management practices would not likely have a significant impact.

Because farmers rely on soils to grow multiple crops like rice and soybeans in addition to crawfish, farmers using rotational crop systems in Louisiana, the region that accounts for 90% of the crawfish production in the United States, drain ponds slowly to prevent loss of soil. Ponds are also drained slowly to encourage crawfish to burrow into the pond bottom to start their reproductive cycle. There are some examples of crawfish farmers discharging water from crawfish ponds into siltation ditches and ponds prior to discharging the effluent into receiving surface waters like streams and rivers (Tetra Tech, 2002d). There is also cooperation with the Natural Resources Conservation Service (NRCS) to implement BMPs to minimize erosion and reduce the amount of nutrients and pesticides in effluent discharges (LSU, 1999). Examples of these practices include channel vegetation to improve turbidity problems, filter strips to reduce sediment in inflow and discharge water and help reduce soil erosion, and irrigation water management with planned flooding and draining to manage forage and crawfish.

BMP guidelines from NRCS also describe the positive environmental impacts of well-managed crawfish ponds (LSU, 1999). In many cases, flooded crawfish ponds benefit and improve the quality of the water entering and exiting fields by developing or restoring wetlands. Crawfish ponds provide more than 115,000 acres of man-made wildlife wetland habitat, benefiting waterfowl, wading birds, shorebirds, furbearers, reptiles, amphibians, and other invertebrate animals.

Although there is limited information about the quality of water discharged from either rotational ponds or permanent ponds, the impact of the volume of water discharged and the quality of the water discharged is likely to be minimal. First, crawfish production relies on the forage-based system for feeding, so feed management practices would not significantly impact water quality because the feed input is so low. Also, although dissolved oxygen levels are a concern, particularly as vegetation decays, crawfish farmers routinely check levels and use BMPs and technologies like mechanical aeration to maintain appropriate dissolved oxygen levels. Crawfish farmers also use siltation ditches to minimize the impact of discharge from crawfish ponds. Finally, when water is discharged from ponds, farmers release the water slowly to prevent the loss of valuable topsoil needed for productive agricultural crops and to encourage crawfish to burrow.

4.3.11 Lobster

The impoundment or pounding of the American lobster (*Homarus americanus*) in tidal lobster pounds is an important part of the lobster industry in Maine. Pounds are man-made tidal pools or impounded coves (Loughlin et al., 2000). They are flushed daily at high tide, replacing the holding area with fresh seawater. Pounds help lobster fishers and pound operators control the supply of lobsters to meet the market demand in the off-season when fishers are not harvesting wild catches. Although pounding is an important practice in Canada, according to the Maine Lobster Pound Association, Maine is the only state in the United States using this cultivation practice (Hodgkins, 2002, personal communication). There are 65 lobster pounds in Maine owned by 50 operators (Hodgkins, 2002, personal communication; Tetra Tech, 2002e).

In 2000, 57 million lb of American lobster with a commercial value of more than $187 million were landed in Maine (Maine, 2002). Most wild-caught lobster harvests are shipped immediately to market, but some are held in pounds to extend their growth cycle. Tidal pounds in Maine hold about 5 million lb, or approximately 10% of the total lobster landed in the state (Hodgkins, 2002, personal communication). In the colonial period, lobsters were considered poverty food, served daily to children, prisoners, and indentured servants (Gulf of Maine Aquarium, 2000). In today's market, the increased demand for lobster and the decline in wild lobster harvests has transformed lobster into a high-priced commodity, thereby encouraging the development of pounding.

4.3.11.1 Production Systems

For fall pounding, lobster fishers sell their catches of newly shed lobsters from September through November to pound keepers, who hold the shellfish in pounds (AII, 1989). Without aeration, lobsters are typically stocked 1 lb per square foot of bottom area. The average size of a lobster pound is 70,000 ft^2 (Hodgkins, 2002, personal communication; Tetra Tech, 2002e). From early September through April, the lobsters fill in their new larger shells with meat while the pound operators wait for a favorable market price. There are also shorter spring and summer pounding seasons with fewer lobsters. Spring pounding starts in May when the Canadian season opens, and spring-pounded lobsters are sold before they molt in July and August. From July to August soft shell lobsters are placed in pounds, where they harden and are sold. Summer pounding caters to the airfreight market (Tetra Tech, 2002e).

Lobsters are harvested using one of three methods: pumpers, dragging, or divers (Loughlin et al., 2000). Because of their speed and efficiency, airlift or hydraulic pumpers are considered the most cost-effective means of harvesting lobsters from a pound. With diver-operated pumpers, a diver works on the bottom, collecting lobsters and placing them into the end of the suction tube. Water flowing through the tube carries the lobsters to the surface. Dragging or seining is another common harvest method; however, lobsters are sometimes crushed or damaged when the work crew hauls the drag over the edge of the platform. Divers are also used to remove lobsters from pounds. They use a mesh bag to collect the lobsters. The bag is attached to a line that extends to the workstation. When the bag is full, the diver signals the crew to haul up the bag. Some pound owners drag their pounds until they recover about 80% of their lobsters; then they use divers to collect another 15%. The remaining lobsters are harvested when the pound is drained (Loughlin et al., 2000).

4.3.11.2 Culture Practices

Feed Management

Pound operators feed lobsters while they are in the pound. Most lobster pound facilities feed lobster freshly killed fish such as sculpin, pickled and smoked herring, and menhaden (Hodgkins, 2002, personal communication). Fresh or salted fish racks can also be used as a food source for lobsters. Operators generally use manufactured feed only when they need to apply medicated feed. The average feeding rate for Maine lobster pounds is approximately 70 lb of fish per day per 5,000 lobsters (Hodgkins, 2002, personal communication; Tetra Tech, 2002e). Winter is the primary pounding season in Maine. On average, lobsters are fed for 40 d within the winter pounding season. Feeding rates drop off when water temperatures drop below 40 °F. When water temperatures approach 32 °F, lobsters begin hibernating and do not consume food during this period. The summer and spring pounding seasons are shorter (1 to 2 mo), with fewer lobsters and very few feeding days (Hodgkins, 2002, personal communication; Tetra Tech, 2002e).

Health Management

The three main diseases that affect lobsters are red tail, vibrio, and ciliated protozoan disease. Red tail (caused by *Gaffkemia*) is a fatal, infectious bacterial disease of lobsters that passes from one lobster to another through a break in the tail (Loughlin et al., 2000). Symptoms of red tail include inactive, weak, and lethargic lobsters; red tint under the tail;

and a tendency in lobsters to remain near the shore (Loughlin et al., 2000). Red tail disease is present in an average of 5% to 7% of wild lobsters (Lobster Institute, 1995). If infected lobsters are placed in a pound and die, the live bacteria cells spread to other lobsters (Gulf of Maine Aquarium, 2000). Gram negative rod bacteria, such as *Vibrio*, are hard to detect and difficult to treat. To stop the spread of the bacteria to healthy lobsters, pounds prevent overfeeding and remove weak lobsters (Loughlin et al., 2000). Ciliated protozoan disease is fatal to lobsters, with mortality usually occurring in 1 to 2 mo (Loughlin et al., 2000). As in red tail, the protozoan enters the lobster through a break or wound in the tail. The disease has no approved treatment and has shown up in more than a dozen pounds over the past 10 yr (Loughlin et al., 2000).

Pound operators conduct an initial health screening of the lobsters before they are stocked into the pound to remove weak and sick animals. This practice reduces the frequency of disease in the pound. Pound operators also conduct periodic inspections using divers or a small hand drag to sample the pond and to screen out sick and dead lobsters (Loughlin et al., 2000).

When needed, pound keepers use medicated feed containing oxytetracyclin (brand name Terramycin) to treat bacterial diseases like red tail. The frequency of use varies from facility to facility. On average, about half of the pound facilities use oxytetracyclin in a pound season. Treatments with medicated feeds usually last 5 d before pound keepers switch back to regular feed, and pound keepers commonly use the drug for two cycles, or 10 d, in a pound season. Oxytetracyclin is administered through medicated feed at approximately 6 to 8 lb of feed per 1,000 lb of lobster. As temperatures drop, feeding rates also decline to 3 to 5 lb of feed per 1,000 lb of lobster. Assuming an average facility holds 70,000 lb of lobster, a facility would use roughly 3,850 lb of medicated feed in a year. (For the entire industry, this would be approximately 127,050 lb of medicated feed per year.)

The FDA regulates the use of medicated feed and requires lobster growers to apply a 30-day withdrawal period. Facilities must wait at least 30 days after feeding lobsters medicated feed before they remove lobsters from the pound to ensure that residues from the medication are flushed from the lobster before human consumption. Currently, oxytetracyclin is the only FDA-approved medication for lobsters (Bayer, 2002, personal communication). Generally, this is the only drug or chemical used by lobster pound facilities.

4.3.11.3 Water Quality Management Practices

Mechanical aeration enhances dissolved oxygen levels in lobster pounds. Approximately two-thirds of lobster pound facilities in Maine use mechanical aeration, especially in months with warm water temperatures (Hodgkins, 2002, personal communication). Dams for the impoundment are built to the height of the mean low water mark with a notch at the mean low water mark. As incoming water flows through this notch at high tide, the increase in water velocity promotes water mixing inside the impoundment (Tetra Tech, 2002e). Pounds rely on tidal flushing to maintain the water quality in the impoundment. Currently, there are no existing control technologies in the industry to reduce discharge.

Although there is little information about the quality of water discharged from lobster pounds, the impact of the effluent is likely to be minimal. Currently, lobster pounds are found only in Maine, and they are not likely to expand to other states. This is a small industry subcategory that is site-specific to Maine. Based on a relatively low input of food and a limited number of feeding days, feed management BMPs are not likely to improve water quality in the system. Regular tidal flushing for all pounds and supplemental aeration for many pounds in Maine also help maintain water quality and dissolved oxygen levels. Finally, the industry is regulated by the FDA 30-day withdrawal requirement limiting the number of days that pound keepers can use medicated feed, so the impact from inputs of medicated feed into the system is likely to be minimal and is already regulated by another agency.

4.3.12 Molluscan Shellfish

Molluscan shellfish AAP systems are used to raise oysters, clams, mussels, and scallops. These animals are bivalves; that is, they have a soft body enclosed by two hard shells or valves. The valves are attached at a hinge and are held shut by a strong muscle. Most cultured molluscan shellfish are filter feeders that rely on phytoplankton and particulate detritus delivered by water currents as their food source (JSA, 2000c).

Oyster farming is practiced on the Atlantic, Gulf of Mexico, and Pacific coasts of the United States. In the United States, two species currently dominate the oyster culture industry: the Pacific or Japanese oyster (*Crassostrea gigas*) and the American oyster (*Crassostrea virginicia*). Oysters usually inhabit areas from low intertidal zone to approximately 45 ft deep, forming a reef-like mass on firm bottom. Depending on the geographic location, oysters take from 18 to 48 mo to reach market size (JSA, 2000c).

Clam farming is widespread throughout the United States, particularly on the east coast. Two species dominate commercial production. The hard clam (*Mercenaria mercenaria*), also known as the quahog, hard-shelled clam, cherrystone clam, or little neck clam, is indigenous to the Atlantic and Gulf of Mexico coasts, with smaller populations present on the west coast. The hard clam prefers relatively protected areas that have stable sandy to muddy bottoms with small amounts of shell. Populations exist from the low intertidal zone to nearly 60 ft in depth. The second species of clam most often cultured in the United States is the Manila clam (*Tapes philippinarum*) on the Pacific coast. Manila clams are typically found in habitats similar to those of the hard clam, but they generally exist slightly higher in the intertidal zone in areas with a coarser substrate like gravel. As with the hard clam, Manila clams have short siphons (necks), and this limits the depth to which they can burrow. Like oysters, clams typically take from 18 to 48 mo to reach market size. Two additional species may be produced commercially in the near future: the geoduck (*Panope abrupta*) on the west coast and the surf clam (*Spisula solidissima*) on the east coast.

Mussel farming is a relatively new sector in the United States. Three principal mussel species are cultivated: *Mytilus edulis* on the east coast and *M. galloprovincialis* and *M. trossulus* on the west coast. Mussels usually form dense aggregations, like reefs, from the low intertidal zone to 30 ft deep. These aggregations may be on hard substrate or stabilized muds or sands. Both species typically reach commercial size in 19 to 24 mo.

Scallop farming, like mussel farming, is also a relatively new sector in the United States. Scallop culture is limited, and most commercial efforts have been confined to the bay scallop (*Argopecten irradians*). This species lives in shallow bays from Massachusetts through Florida and is often associated with beds of eelgrass (JSA, 2000c). Cultured scallops reach commercial size in 10 to 24 mo. There is also a growing interest in the northeastern United States in the sea scallop (*Placopecten magellanicus*), but currently these efforts are experimental. In Washington there is a project exploring the possibility of culturing the rock scallop (*Hinnites giganteus*).

Harvest data related specifically to the molluscan shellfish industry are very limited and inconsistent (Kraeuter et al., 2000). Shellfish production as reported by most states is not divided based on whether the shellfish are cultured or from a wild harvest fishery, and there is no consistency among states regarding reporting units. For example, some states report oysters by live weight and some in shucked meat weight. Based on data from the 1998 Census of Aquaculture (USDA, 2000), there are 535 molluscan shellfish farms in the United States—268 in the Southern Region, 150 in the Northeastern Region, 108 in the Western Region, 5 in the Tropical/Subtropical Region, and 4 in the North Central Region. Though it has fewer facilities, the Northeastern Region leads the country in revenue with approximately $26.7 million in total sales, followed by the Southern Region with $24.7 million in total sales.

4.3.12.1 Production Systems

Shellfish AAP activities vary widely throughout the United States. Different species are cultured in different regions and use a variety of culture systems. Determining what is actually AAP is a challenge (Kraeuter et al., 2000). On one end of the spectrum are managed wild fisheries, which rely on natural recruitment to reseed public beds. At the other end of the spectrum is intensive culture on privately owned tidelands. Beds are seeded with juveniles that began as larvae in a hatchery, raised in an upland nursery on cultured algae, transferred to a land-based nursery that relies on natural algae present in the water, and finally planted in some sort of growout system. Between these two ends of the spectrum are a range of other options with varying levels of control over the product being cultured.

Intertidal culture, or shallow-depth culture (less than 3 ft), is the most common bottom culture in the United States. Intertidal techniques vary and are dependent on the species being cultured. Clams, oysters, and mussels may be placed directly on the bottom in beds. Clams dig in, whereas oysters and mussels remain on the bottom surface. In clam culture, mesh is usually placed over the clams or they are placed in mesh bags to prevent predators from consuming the crop. Oysters and mussels are usually planted without protective devices; in Washington's Puget Sound, however, farmers sometimes use plastic mesh bags, which are attached to the bottom on a longline. Intertidal plantings of oysters and mussels can also be suspended above the bottom on racks, trays, longlines, or bags strung on lines or wrapped on pilings. These techniques usually suspend the crop 1 or 2 ft off the bottom and rely on tidal action to feed the animals and remove wastes.

Subtidal water column culture is used where tidal amplitudes are not sufficient to support intertidal beds or where the organisms do not require sediment. Scallops, mussels, and oysters are cultured in subtidal water column systems. Water column culture in deeper waters, or floating culture, uses either rafts or longlines attached to floats, or a tray or rack system. Tray systems require specialized diving or lifting gear for maintenance in deeper waters. Subtidal water column culture is less common in the United States because these systems require floats or rafts on the surface that create conflicts with competing recreation or commercial uses of the water surface or column, as well as concerns from upland owners regarding visual impact.

4.3.12.2 Culture Practices

The intensive culture of molluscan shellfish has five phases: food production, broodstock maintenance/conditioning, hatchery, nursery, and growout.

Bivalve hatcheries are used to condition (i.e., prepare for spawning) broodstock, spawn animals, and raise larvae. Food for conditioning broodstock, larval, and post-set bivalves consists of various forms of unicellular algae that are grown and added to the water for the bivalve to filter (Kraeuter et al., 2000). The production of algae is one of the most time-consuming and expensive parts of bivalve culture. There are two methods for producing phytoplankton for use as food for molluscan shellfish. The Wells-Glancey method involves filtering raw seawater to remove large diatoms and algae consumers, such as copepods, and enriching the filtrate to promote the growth of small diatoms and flagellates. This method is inexpensive, but it provides little control over the species cultured. The Milford method uses a single species of phytoplankton in bacteria-free or clean, but not contaminant-free, cultures. This method provides more control over algal growth, but the need to maintain cultures and sterile conditions increases the expense.

Broodstock are used to produce the gametes for the next generation. Most broodstock are maintained in field sites until they are to be conditioned, the process of gonadal maturation for spawning. The animals are brought into a hatchery where water temperatures can be controlled to manipulate spawning. Animals to be spawned are placed in tanks and slowly warmed, and then cultured algal food is added to the water. Tanks range in size from 150 to 500 gal. This process is a batch culture, and water is typically exchanged every 2 d (Kraeuter et al., 2000). The conditioning phase takes approximately 6 to 8 wk. A small hatchery may condition 50 to 100 animals, and a larger hatchery may condition up to 2,000 animals. Only algal food is added to the water during this phase.

With strip spawning, eggs or sperm are removed from the animal, and the eggs are fertilized and placed in a tank of filtered seawater. Mass or individual spawning is achieved by placing the animals in a seawater bath. In most instances, volumes of water used are small (usually less than 100 gal) because hatcheries minimize the amount of water for which they need to control the water temperature. Once spawning begins, the eggs are retained in a dish, or a container for single spawning individuals. In mass spawning, fertilization takes place in a tray with animals. After the eggs hatch the larvae are fed algae beginning on the second day. Water is exchanged every 1 or 2 d. Some hatcheries use flow-through systems with screens to prevent the escape of larvae. The number of days in larval culture varies, but typically ranges from 14 to 20 d.

Setting is the process by which a bivalve grows a shell and changes from a planktonic, pelagic animal to a benthic animal. Though procedures vary from species to species, usually the animals are set and maintained with food inputs of cultured algae. Oysters may be set at the hatchery or moved to a remote site, where they are added to tanks that have been filled with bags of shell and filtered seawater and some unicellular algal food. The tanks are aerated. Setting can take 1 to 3 d, and individuals may remain in the tank for 1 to 3 wk before they are placed in a field nursery. Clams, scallops, and mussels are all set by attaching to a substrate by their byssal threads. These animals are removed from the larval culture tanks and placed in downwellers (cylinders with a mesh bottom through which water is passed by pumping it in through the top), in bags of setting material, or in trays. Many of these methods continue to feed with unicellular algae for 1 to 2 wk and then transition to a nursery culture.

Nurseries hold animals until they are ready to be planted in the substrate. The longer the larvae, or seed, can be raised in protected nursery systems, the higher the survival rate will be when they are planted in the final growout phase. As with the hatchery phase, the number of animals being cultured in a nursery is large, but the biomass is very small when compared to fish or crustacean culture (Kraeuter et al., 2000). Nurseries use two different culture methods: induced circulation and natural circulation. Induced circulation uses pumps, paddlewheels, or airlifts to move large volumes of water to create a flow so the bivalves can filter feed. For natural circulation, animals are placed in bags suspended in the water or on trays on the bottom, and natural circulation moves water over the animals to bring them food and remove waste. Animals are usually kept in a nursery until they are large enough to be planted. For most bivalve nurseries, the individuals increase in size from 1 mm to 10–20 mm (Kraeuter et al., 2000). The only significant addition to the production water in this phase is the freshwater used to wash the seed and flush the trays, upwellers, raceways, or sieves. Some nursery facilities also add cultured algae to the system, but costs limit this practice.

The growout phase is the last phase in bivalve culture. Some producers buy seed and focus only on growout. All growout techniques for bottom culture rely on naturally occurring food sources at the site. There are no feed management practices because there is no feed input.

Feed Management

Bivalve (molluscan) AAP is substantially different from other forms of AAP in that no food is added to the culture water during the growout phase (Kraeuter et al., 2000). Shellfish are grown out in the open, protected coastal waters. They feed by filtering large volumes of seawater through their gills and extracting natural phytoplankton present in estuaries. Depending on the species, size, water temperature, and other variables, volumes of water filtered can range from 20 to 80 gal/d, per animal (Kraeuter et al., 2000). This demand at the growout stage for high volumes of water and physical space generally requires that molluscan shellfish are produced in the natural environment.

Although hatcheries and some nurseries add cultured algae to the water as a food source, the impact from this addition is not significant. The risk of nonindigenous microalgae grown for shellfish feed disrupting natural phytoplankton ecology is very low (Wikfors, 1999, personal communication). Cultured algae strains have been sheltered in artificial culture conditions. If they were to escape, they would most likely have lost most of their ability to compete with indigenous phytoplankton. Furthermore, there have been no examples of nonindigenous algal strains from shellfish hatcheries creating a bloom or even a low-level introduction in receiving waters.

Health Management

Drug and chemical use in molluscan shellfish culture is very limited. The common industry practice is to maintain bacteria at low levels in the early stages of culture by sterilizing the water (Kraeuter et al., 2000). It is not economically feasible to use drugs to control disease in bivalves. If hatcheries use chlorine to clean tanks or sterilize seawater, these facilities are required to dechlorinate prior to discharge (Tetra Tech, 2001). Abalone culture is the only culture activity that uses spawning aids like hydrogen peroxide and L-Dopa to enhance settlement. For bivalves, research facilities are the primary users of any other chemicals or drugs (Tetra Tech, 2001).

4.3.12.3 Water Quality Management Practices

The importance of bivalve filtration, or lack of filtration, in natural systems has been used as an argument for restoring the abundance of oysters in the Chesapeake Bay and the New York harbor through either AAP or natural reef restoration (Revkin, 1999; Zimmerman, 1998). Restoring this filter feeding population would increase dissolved oxygen and water clarity and remove nitrogen and phosphorus from the system through direct harvest (Newell and Ott, 1999). The ecological consequence of this current lack of filter feeders is significant. Rice et al. (1999) have estimated that the northern quahog (hard clam) could remove up to 167,000 lb of nitrogen from the water column and that sustainable harvest of the population would completely remove 17,000 lb of organic nitrogen annually. Another study found that an intensive mussel culture raft system increased the rate of energy flow, as well as nitrogen and phosphorus deposition and regeneration; but unlike fish farming, the mussel culture did not cause eutrophication by nutrient input (Rodhouse and Roden, 1987). Still another study proposes the use of mussels as a means to clean up eutrophied fjord systems in Sweden (Haamer, 1996).

Fertilizers used in hatcheries are not likely to affect receiving waters. The fertilizer mix used in shellfish hatcheries is designed to be deficient in nitrogen, the nutrient of most concern in coastal eutrophication (Wikfors, 1999, personal communication). Nitrogen is the limiting factor for phytoplankton growth. The standard hatchery operation involves growing algae to a density at which all nitrogen is assimilated by the microalgae and the algae stop growing.

The growout phase of molluscan shellfish production does not add food to the system. The bivalves rely on natural food found in coastal waters. In terms of a mass balance, materials are extracted from the estuary as they are converted into bivalve flesh and shell, or used for respiration (Kraeuter et al., 2000). Because there is no feed input, there are no feed management practices. Bivalve culture can actually result in the net removal of nitrogen, phosphorus, and other pollutants when crops are harvested and removed from the system (Kraeuter et al., 2000). Because bivalves filter nutrients out of the water, they do not pose a threat to water quality. EPA believes there is little, if any, impact on water quality; therefore, no current technologies or BMPs are being used by this industry subcategory.

4.3.13 Other Aquatic Animal Production (Alligators)

American alligators (*Alligator mississippiensis*) are raised in captivity primarily for their hides and meat. The leather is used to make luxury apparel items such as belts, wallets, purses, briefcases, and shoes. In the past the high value of these leather products led to extensive hunting of alligators in the wild. By the 1960s this exploitation, plus loss of habitat, had depleted many wild populations (Masser, 2000). Research into the life history, reproduction, nutrition, and environmental requirements of the American alligator, along with the rapid recovery of wild populations, led to the establishment of commercial farms in the United States in the 1980s. In 1996 wild harvest and farm-raised alligators from the United States supplied more than 240,000 hides to world markets. Approximately 83% of these hides were from alligator farms (Masser, 2000). States with licensed alligator farms are Alabama, Florida, Georgia, Idaho, Louisiana, Mississippi, and Texas.

The American alligator was once native to the coastal plain and lowland river bottoms from North Carolina to Mexico (Masser, 2000). The only other species of alligator (*A. sinensis*) is found in China and is endangered. Hunting alligators for their hides began in the 19^{th} century. At the turn of the 20^{th} century, the annual alligator harvest in the United States was around 150,000 animals. Overharvesting and habitat destruction depleted the wild population, and by the 1960s, most states had stopped allowing alligator hunting. To protect alligators from further exploitation, they were designated under the Endangered Species Act as endangered or threatened throughout most of their range, with the exception of Louisiana. Alligator populations recovered quickly, particularly in Louisiana, which had stopped legal harvesting in 1962 (Masser, 2000). Louisiana reopened limited harvesting of wild alligators in 1972, but the population continued to increase even with sustained harvesting. Most other southern states also experienced population increases after federal protection.

In 1983, under the CITES, the U.S. Fish and Wildlife Service changed the designation for the American alligator to "threatened for reasons of similarity in appearance" (Masser, 2000). This classification means that the alligator is not threatened or endangered in its native range; however, the sale of its products must be strictly regulated so that the products of other crocodilian species that are endangered are not sold illegally as those of American alligators. Today, in addition to alligator farming, nuisance control is allowed in several southern states, and limited harvests from the wild are permitted in Louisiana, Texas, and Florida (Masser, 2000).

Alligators inhabit all types of fresh to slightly brackish aquatic habitats. Males grow larger than females, and growth and sexual maturity are dependent on climate and the availability of food (Masser, 2000). Along the Gulf coast, females usually reach sexual maturity at a length of 6.5 ft and an age of 9 to 10 yr. As in other cold-blooded animals, maturation age is affected by temperature. Optimum growth occurs at temperatures between 85 and 91 °F (Masser, 2000). No apparent growth takes place below 70 °F, and temperatures above 93 °F cause stress and sometimes death.

In the wild, young alligators usually consume invertebrates such as crawfish and insects. As they grow, fish become a part of their diet. Adults consume mammals such as muskrats and nutria. Large adult alligators even consume birds and other reptiles, including smaller alligators (Masser, 2000). Females do not move or migrate over long distances once they have reached breeding age, and they prefer heavily vegetated marsh habitat. Males move extensively but prefer to establish territories in areas of open water.

4.3.13.1 Production Systems

Alligator farming uses a unique production system that is not easily categorized as either a pond system or a flow-through system. Alligator systems use more water than typical pond systems and less water than typical flow-through systems. Available literature suggests that pond-like systems, in the form of outdoor ponds and lagoons, are most often used for raising and maintaining breeding alligators for a source of eggs. Young alligators are typically raised for growout in indoor pens with shallow pools that use concrete tanks to hold the animals. Within the concrete tanks, water is usually pumped from a well and then heated before it is pumped into the pools of each pen. At some facilities, water in the indoor pools is completely drained and replaced daily or every other day to maintain good water quality (Coulson et al., 1995). Some facilities drain less frequently. Maintaining water temperature and minimizing heating costs are often major concerns of alligator farmers. Based on daily drainings, the production system could be described as a batch-like flow-through system with a daily exchange of water. When facilities drain less often, the system could be described as a pond with frequent drainings.

In an effort to reduce costs, some producers are using outside growout facilities (Masser, 2000). In this system, alligators are raised in indoor facilities for the first year of growth and then moved to outdoor fenced ponds. The alligators are fed a commercial diet during warm weather and are allowed to hibernate during cooler seasons. After about 2 yr, the ponds are drained, usually during the winter, to facilitate handling and harvesting of the animals.

4.3.13.2 Culture Practices

The commercial production of alligators can be divided into three phases: management of adult alligators for breeding; egg collection, incubation, and hatching; and growout of juvenile alligators to market size. Alligator farmers must either purchase eggs or hatchlings from other producers or produce their own eggs. In Louisiana, Florida, and Texas, eggs and/or hatchlings can be taken from the wild under special permit regulations. Today, the primary source for eggs is wild populations; however, Louisiana law does not allow the sale of alligator eggs outside Louisiana.

Some farmers have completely integrated operations with their own breeding stocks, hatching facilities, nursery facilities, and growout houses, but most alligator farmers focus on only growout operations (Jensen, 2000, personal communication). This approach is also called ranching, an open-cycle system that does not maintain adult breeders or produce its own stock, similar to a cattle feedlot operation (Lane and King, 1996). With growout operations, hatchlings are purchased from a farm or ranch specializing in the production of hatchlings, usually from eggs collected from wild stocks. Most of the eggs used to produce hatchlings are collected on private lands, which provide a source of income to marsh landowners who, in turn, maintain and manage wetland habitat for the benefit of the alligator population. Egg collection from wild populations is regulated by state agencies that set site-specific quotas for the number of nests that may be harvested (Heykoop and Freschette, 1999). Hatchlings may also be available from state agencies that regulate wild populations. The wild population is a source of young stock for domestic populations, and in Louisiana, where a percentage of hatchlings is returned to the wild, the domestic population is a source of juveniles for the wild populations (Heykoop and Freschette, 1999).

The first phase, maintaining adult alligators and achieving successful and consistent reproduction, is extremely difficult and expensive (Masser, 1993a). Adult alligators that have been raised entirely in captivity or confinement behave differently from wild stock. Farm-raised alligators accept confinement and crowding as adults better than wild alligators. Also, adult alligators raised together tend to develop a social structure, adapt quicker, and breed more successfully than animals without an established social structure.

For the few farms that maintain breeding stocks or specialize in producing eggs, pens for adult alligators are built approximately 1 to 2 ac in size (Masser, 1993a). Pens must be carefully fenced to prevent the escape of the adult alligators. Breeding pen design, particularly the water ratio and configuration, is very important. The land area-to-water area ratio in the pen is approximately 3:1, and the shape of the pond maximizes the shoreline area with an ‘S’ or ‘Z’ shape. The depth of the breeding pond is at least 6 ft. Breeding ponds have dense vegetation around the pond to provide cover, shade, and nesting material. Alligators burrow into the pond banks if adequate shade is not provided. Stocking densities for adult alligators are approximately 10 to 20 animals per acre. The female-to-male ratio should be approximately 3:1.

Adult breeders should be disturbed as little as possible from February through August, during egg maturation, courting, and nesting. Nesting success in captive alligators has been highly variable. Wild versus farm-raised origin, pen design, density, the development of social structure within the group, and diet all affect nesting (Masser, 2000). Nesting rates for adult females in the wild averages around 60% to 70% with the most favorable habitat and environmental conditions. Nesting rates in captivity are usually much lower (Masser, 2000). Clutch sizes vary with the age and condition of the female, with larger and older females usually laying more eggs. Clutch size averages around 35 to 40 eggs and egg fertility varies from 70% to 95%. Survival of the embryo also varies from 70% to 95% and the hatching rate from 50% to 90%. Land costs, long-term care of adults, and low egg production contribute significantly to the cost of maintaining breeding stocks (Masser, 2000).

The method and timing of egg collection are very important; alligator embryos are very sensitive to handling from 7 to 28 d after the eggs are laid (Masser, 2000). Eggs should be collected in the first week or after the fourth week of natural incubation. When eggs are collected, they must be kept in the same position and not turned or rotated during handling. Compared with wild nesting, artificial incubation improves hatching rates because of the elimination of predation and weather-related mortality (Masser, 2000). The best hatching rates for eggs left in the wild are less than 70%, while hatching rates for eggs taken from the wild and incubated artificially average 90% or higher (Masser, 2000).

Eggs should be transferred into incubation baskets and placed in an incubator within 3 or 4 h after collection. Eggs are completely surrounded with nesting material like grasses and other vegetation. The natural decomposition of the nesting materials helps with the breakdown of the eggshell. The incubation temperature is critical for the survival and development of the hatchlings. Temperature also determines the sex of the alligator. Temperatures of 86 °F or below produce females, and temperatures of 91 °F or above produce males. Temperatures much above or below these ranges result in high mortalities (Masser, 2000). After the alligators hatch, the hatchling are kept in the incubation baskets for the first 24 hours and then moved to small tanks heated to 86 to 89 °F. Maintaining 89 °F helps hatchlings absorb the yolk. Usually, hatchlings will begin to feed within 3 d. Once hatchlings are actively feeding, they can be moved into growout facilities.

A variety of growout facilities are used for raising alligators. Growout buildings are usually heavily insulated concrete block, wood, or metal buildings with heated foundations. They usually do not have windows. Most animals are kept in near or total darkness except during feeding and cleaning times. The concrete slab is lined with hot water piping or, sometimes, electric heating coils. A constant temperature is maintained by pumping hot water through the pipes. Covering about two-thirds of each pen is a pool of water about 1 ft deep at the drain. The bottom of the pool is sloped down toward the drain to facilitate cleaning. The remaining one-third of the pen area is above water and is used as a feeding area and basking deck (Masser, 1993b). Pens vary in size. In general, smaller pens are used for smaller alligators and larger pens are used as alligators grow. Usually, farmers construct several sizes of growout pens and reduce the density by moving the animals as they grow. Common stocking densities include 1 ft^2/animal until the animal reaches 2 ft in length; 3 ft^2/animal until the animal reaches 4 ft in length; and 6 ft^2/animal until the animal reaches 6 ft in length.

A common construction plan uses a 5,000-ft^2 building with an aisle down the middle and pens on either side. A 4-ft aisle creates pens that are approximately 14 ft wide. Pens are usually 13 ft long with a 3-ft concrete block separating individual pens from the aisle. Another popular building design is the single round house, a structure about 15 to 25 ft in diameter constructed as a single pen (Masser, 2000). Round houses have also been built from concrete blocks, or from a single section and roof of a prefabricated metal silo used for storing grain. The round concrete slab on which the house sits is sloped from the outer edge toward a drain in the center of the structure. The round house is filled with water so that approximately one-third of the floor is above the water level. Because they are single-pen units, round houses have the advantage of not disturbing alligators in other pens during feeding, cleaning, and handling operations.

The heating system, which consists of water heaters and pumps, is an important part of the growout facility. Warm water is needed to heat the building, fill the pools, and clean the pens. Some heating systems have industrial-size water heaters, while other systems have flash-type heaters to heat water for cleaning and standard heaters to circulate warm water through the slab. Thermostats regulate the temperature and circulation pumps. The temperature in growout pens must be between 86 and 88 °F for optimal growth (Masser, 2000).

Written approval and hide tags must be obtained from the appropriate state regulatory agency before any alligators may be harvested. Some states also require a minimum length of 6 ft at harvest. Alligators may be skinned only at approved sites. Skinning, scraping, and curing must be done carefully to protect the quality of the skin; hides that are cut, scratched, or stretched have a reduced value. Most hides are sold to brokers, who purchase and hold large numbers of hides and then sell them to tanneries for processing. A few larger farms sell directly to the tanneries, the best of which are in Asia and Europe.

Feed Management

In general, alligators in the wild consume a diet high in protein and low in fat. Early alligator producers manufactured their own feed using inexpensive sources of meat like nutria, beef cattle, horse, chicken, muskrat, fish, and beaver. Today, several feed mills are manufacturing pelleted alligator feed. Most farmers feed their animals only commercially available feed; however, some continue to feed the animals a combination of raw meats and commercial diets.

Feed is spread out on the deck in small piles to reduce competition. Typically, farmers feed alligators 5 times per week, although some may feed 6 or 7 d/wk. The feeding rate is roughly 25% of the animal's body weight per week the first year; then the rate is gradually reduced to 18% of body weight as the animal approaches 3 yr old or a length of 6 ft. Feed conversion efficiencies decrease as alligators grow larger. The food conversion ratio is between 2:1 and 3:1 (Masser, 2000). Monthly growth rates in alligators can be as high as 3 in. when the temperature is held at a constant 86 to 89 °F and they are fed a quality diet with minimal stress. Many producers grow hatchlings to 4 ft in 14 mo, and some producers have grown alligators to 6 ft in 24 mo (Masser, 2000).

Health Management

There is very little information available in the literature to characterize drug and chemical use for alligator farming. No antibiotics are approved for use on alligators; therefore, any antibiotics needed must be obtained through a prescription from a veterinarian (Masser, 2000). Two antibiotics, oxytetracycline and virginiamycin, have been used by alligator producers and added to feed to fight bacterial infections (Masser, 1993b).

Alligators need clean water to maintain the quality of their skins. Poor water management can lead to brown spot disease, which scars the skin and reduces its value (Masser, 1993b). After pools are drained, veterinarians suggest that the refill water contain 1 to 2 mg/L of chlorine to reduce bacteria and fungi (Schaeffer, 1990).

4.3.13.3 Water Quality Management and Effluent Treatment Practices

Raw wastewater from alligator production facilities closely resembles domestic wastewater. The major difference is that alligators tend to excrete approximately twice the amount of ammonia per body mass when compared to humans (Pardue et al., 1994). The concentrations of various alligator raw wastewater constituents are presented in Table 4.3-11.

Effluent treatment practices vary significantly from facility to facility. Most facilities use oxidation ponds or lagoons to treat effluent from the raising operations. In some cases, facilities have begun to experiment with the use of "package plants" to treat raw wastewater before it is recycled for cleaning purposes. These "plants" are small filtration units designed for the needs of individual facilities.

Table 4.3-11. Pollutant Concentrations in Alligator Raw Wastewater

Parameter	*Concentrations (mg/L)*
Ammonia	77.5
Nitrate	4.6
TKN	153.4
Total phosphorus	10.9
Soluble phosphorus	7.6
BOD_5	452
pH	6.9
Calcium	13.4
Magnesium	5
Sodium	14.8
Conductivity	650
Total solids	379
Volatile solids	219

Source: Pardue et al., 1994.

4.4 TRENDS IN THE INDUSTRY

Based on an estimated increase in population in the United States from 270 million in 1998 to 310 million in 2015, it is likely that the U.S. demand for AAP products will continue to increase (Tomasso, 2002). The dependency of the United States on imported seafood might also be a factor in the future growth of AAP in this country. As world capture fisheries continue to decline and collapse, it is likely that AAP products will provide a source to meet the growing demand for fish products. Recently, American consumers have demanded more fresh seafood rather than canned or cured. If the trend toward fresh seafood continues, AAP will provide an important supply (Tomasso, 2002).

Despite an anticipated increase in demand for AAP products, the opportunities for expansion within the industry are limited by the demands of production systems. For pond systems, there are limited sites available with suitable land and water supplies for additional pond facilities. Increased profitability for production in pond systems will depend on improving efficiencies in farm management.

The expansion of flow-through systems is also limited by the availability of appropriate sites with suitable water sources. Development of this sector will depend on increased demand and its impact on profitability based on price. It is likely that conventional flow-through systems will be modified to some form of recirculating system or partitioned AAP system.

Recirculating systems have potential for expansion with continued research and technology development. There is a great deal of interest in recirculating systems because of their ability to reuse and recycle water. Although they are too expensive to use for the production of most species at this time, recirculating systems have the potential to expand in the future because they rely on smaller spaces for their facilities and use less water.

For net pen systems, limited nearshore sites are available for aquatic animal production, and net pens are not permitted in the Great Lakes. There are potentially an unlimited number of offshore sites, but the technology to support these offshore sites is expensive and not fully developed. This option is not likely to be developed in the near future while it is still less expensive to import salmon from other countries.

4.5 AQUATIC ANIMAL PRODUCTION SIZE CATEGORIES

EPA developed the production rate thresholds based on 1998 Census of Agriculture (USDA, 2000) data and the AAP Screener data (Westat, 2002), which were available prior to proposal. Six production size categories, based on revenue classifications used in the 1998 Census of Agriculture ($1,000 to $24,999; $25,000 to $49,999; $50,000 to $99,999; $100,000 to $499,999; $500,000 to $1,000,000; and more than $1,000,000), were used to group facility production data reported in the screener surveys. EPA used national average product prices, taken from the 1998 Census of Aquaculture, to estimate the production (in pounds) for the dominant species reported grown in flow-through systems (e.g., trout, salmon, tilapia), recirculating systems (e.g., tilapia, hybrid striped bass), and net pen systems (e.g., salmon). For alligator systems reported in the screener survey, data from industry reports were used to estimate production value and create groupings of the facilities. EPA used this size classification grouping to more accurately estimate costs, loadings, non-water quality impacts (NWQIs), and economic impacts of the proposed limitations and standards for each of the size classifications within the various species (or aquatic animal types) cultured in this industry. That is, rather than assume one model facility for each of the three regulatory subcategories, EPA used a minimum of six model facilities for each facility type (e.g., commercial, government, research, tribal) and species size combination (e.g., fingerlings, stockers, food-size) for better accuracy in its analyses. EPA applied these size classifications to the screener survey data to derive the model facility characteristics that have been used to support this proposed regulation.

In evaluating the screener data related to facility annual production, EPA identified several variables distinguishing various types of facilities. Concentrated aquatic animal production (CAAP) facilities varied by type of facility operation (species and production method) and type of wastewater management (e.g., direct discharger, indirect discharger, no discharge/wastes applied to land on site). EPA identified annual production levels (by mass) at facilities and then identified the corresponding annual revenue thresholds. For the purposes of estimating costs, loads, economic impacts, and NWQIs, EPA used facility-level production and revenue data to project facilities that would meet the definition of a CAAP facility as defined in 40 CFR 122.24 and Appendix C to Part 122. The Small Business Administration's (SBA's) standard to determine a "small business" in the AAP industry is $750,000 annual revenues at the company level.

EPA is using the results of the revised production rate thresholds to exclude most smaller AAP facilities from the scope of the proposed rule because the Agency anticipates that the technologies on which the options are based would not be affordable (and in some cases would be cost-prohibitive) for the facilities with the lowest production threshold (the smallest facilities). The production-based thresholds for the proposal, however, are based on available screener survey data. EPA intends to conduct more detailed evaluations of these thresholds using responses to the detailed survey. Further evaluation may warrant a change in the proposed production-based thresholds.

4.6 INDUSTRY DEFINITION

The aquatic animal production industry includes sites that fall within the North American Industry Classification System (NAICS) codes 112511 (finfish farming and fish hatcheries), 112512 (shellfish farming), 112519 (other animal aquaculture), and part of 712130 (aquariums, part of zoos and botanical gardens). The first three groups (NAICS 112511, 112512, and 112519) have SBA size standards of $750,000, while the SBA size standard for NAICS 712l30 is $5.0 million. SBA sets up standards to define whether an entity is small and eligible for Government programs and preferences reserved for "small business" concerns. Size standards have been established for types of economic activity, or industry, generally under the NAICS. Refer to 13 CFR Part 121 for more detailed information. EPA uses these SBA size standards to conduct preliminary analyses to determine the number of small businesses in an industrial category and whether the proposed rule would have a significant impact on a substantial number of small entities.

4.7 REFERENCES

AII (Aeration Industries International, Inc.). 1989. *Lobster Pounds Add Weight and Profits*. Aeration Industries International, Inc., Minneapolis, MN.

Avault, J. 1996a. *Fundamentals of Aquaculture*, pp 188-192. AVA Publishing, Baton Rouge, LA.

Avault, J. 1996b. *Fundamentals of Aquaculture*, pp 75-77. AVA Publishing, Baton Rouge, LA.

Bayer, B. 2002. Lobster Institute, Orono, ME. Personal communication, January 23, 2002.

Bengtson, D.A., and G. Nardi. 2000. Summer Flounder Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 907-913. John Wiley and Sons, Inc., NY.

Bergheim, A., J.P. Aabel, and E.A. Seymour. 1991. Past and Present Approaches to Aquaculture Waste Management in Norwegian Net Pen Culture Practices. In *Nutritional Strategies and Aquaculture Waste*, *Proceedings of the 1st International Symposium on Nutritional Strategies and Management of Aquaculture Waste, University of Guelph, Ontario, Canada*, ed. C.B. Cowey and C.Y. Cho, pp. 117-136.

Billard, R., and J.O.T. Jensen. 1996. Gamete Removal, Fertilization, and Incubation. In *Principles of Salmonid Culture*, ed. W. Pennell and B.A. Burton, pp. 291-364. Elsevier Science, Amsterdam, The Netherlands.

Boardman, G.D., V. Maillard, J. Nyland, G.J. Flick, and G.S. Libey. 1998. *The Characterization, Treatment, and Improvement of Aquacultural Effluents.* Departments of Civil and Environmental Engineering, Food Science and Technology, and Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Boyd, C.E. 1990. *Water Quality in Ponds for Aquaculture*. Alabama Agricultural Experiment Station, Auburn University, Auburn, AL.

Boyd, C.E. 2000. Farm Effluent During Draining for Harvest. *The Global Aquaculture Advocate* (August):26-27.

Boyd, C.E., and J.W. Clay. 1998. Shrimp Aquaculture and the Environment. *Scientific American* (June):42-49.

Boyd, C.E., J. Queiroz, J. –Y. Lee, M. Rowan, G. Whitis, and A. Gross. 2000. Environmental Assessment of Channel Catfish (*Ictalurus punctatus*) Farming in Alabama. *Journal of the World Aquaculture Society* 31:511-544.

Boyd, C.E., and C.S. Tucker. 1995. Sustainability of Channel Catfish Farming. *World Aquaculture* 26(3):45-53.

Boyd, C.E., and C.S. Tucker. 1998. *Pond Aquaculture Water Quality Management*. pp. 541-575. Kluwer Academic Publishers, Norwell, MA.

Browdy, C.L., and D. Bratvold. 1998. *Preliminary Development of Biosecure Shrimp Production System*. U.S. Marine Shrimp Farming Program Biosecurity Workshop, February 1998.

Browdy, C.L., and A.F. Holland. 1998. Shrimp Virus Risk Management: A South Carolina Case Study. *Aquatic Nuisance Species Digest* 2(3, February).

Browdy, C.L., A.D. Stokes, and P.A. Sandifer. 1996. *Shrimp Farm Management: Meeting the Challenges*. Waddell Mariculture Center, Proceedings of the International Forum of Shrimp Culture, August 1, 1996.

Brunson, M.W., and H.R. Robinette. 2000. Sunfish Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 913-917. John Wiley and Sons, Inc., NY.

Bury, D., and J.S. Graves. 2000. Status of Knowledge of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), Gulf of Mexico Sturgeon (*A. oxyrinchus desotoi*), Shortnose Sturgeon (*A. brevirostrum*), White Sturgeon (*A.transmontanus*), and Bester Hybrid Sturgeon (*Huso huso* x *A. ruthenus*) as It Relates to Risks for Their Culture in the State of Florida. Revised August 2000. In *Proceedings of the Florida Sturgeon Culture Risk Assessment Workshop,* April 6-7, 2000, Sarasota, FL.

Cain, K., and D. Garling. 1993. *Trout Culture in the North Central Region*. North Central Regional Aquaculture Center. Lansing, MI.

Chapman, F.A. 2000. Ornamental Fish Culture, *Freshwater*. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 602-610. John Wiley and Sons, NY.

Clarke, W.C., R.L. Saunders, and S.D. McCormick. 1996. Smolt Production. In *Principles of Salmonid Culture*, ed. W. Pennell and B.A. Burton, pp. 517-567. Elsevier Science, Amsterdam, The Netherlands.

Clarke, W.C. 2000. Smolting. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 879-884. John Wiley and Sons, NY.

Collins, C., and N. Stone. 1999. Arkansas Aquaculture Production 1998. *Aquaculture Magazine* 25(4):64-66.

Conte, F.S., S.I. Doroshov, P.B. Lutes, and E.M. Strange. 1988. *Hatchery Manual for the White Sturgeon,* Acipenser transmontanus *Richardson, With Application to Other North American Acipenseridae*. Publication 3322. Cooperative Extension, University of California Division of Agriculture and Natural Resources, Berkeley, CA.

Coulson, R.A., T.D. Coulson, and J.D. Herbert. 1995, December. Some Comments on Growing Alligators. Supplement to *Gator Tales*, Louisiana Alligator Farmers and Ranchers Newsletter.

D'Abramo, L.R., and M.W. Brunson. 1996a, July. *Biology and Life History of Freshwater Prawns*. SRAC publication no. 483. Southern Regional Aquaculture Center, Stoneville, MS.

D'Abramo, L.R., and M.W. Brunson. 1996b, July. *Production of Freshwater Prawns in Ponds*. SRAC publication no. 484. Southern Regional Aquaculture Center, Stoneville, MS.

Davis, J.T. n.d. *Crawfish Production*. Special project no. 87-EXCA-3-0836. U.S. Department of Agriculture, Cooperative State Research Service and Extension Service, Washington, DC.

Davis, J.T., and J.T. Lock. 1997, October. *Culture of Largemouth Bass Fingerlings*. SRAC publication no. 201. Southern Regional Aquaculture Center, Stoneville, MS.

de la Bretonne, L.W., Jr., and R.P. Romaire. 1990a. *Crawfish Production: Harvesting, Marketing, and Economics*. SRAC publication no. 240. Southern Regional Aquaculture Center, Stoneville, MS.

de la Bretonne, L.W., Jr., and R. P. Romaire. 1990b. *Crawfish Culture: Site Selection, Pond Construction and Water Quality*. SRAC publication no. 240. Southern Regional Aquaculture Center, Stoneville, MS.

Deniseger, J., and L.J. Erickson. 1998. *Salmon Aquaculture in Broughton Archipelago: the Results of a Sediment Sampling Program — 1996/97, A Data Report*. Ministry of Environment, Lands, and Parks, Pollution Prevention and Pesticides Management, Environmental Section, Nanaimo, British Columbia.

Dierberg, F.E., and W. Kiattisimkul. 1996. Issues, Impacts, and Implications of Shrimp Aquaculture in Thailand. *Environmental Management* 20(5):649-666.

Doroshov, S.I. 2000. The Escape of Cultured Sturgeon and the Interbreeding with Wild Stock. In *Proceedings of the Florida Sturgeon Culture Risk Assessment Workshop*. April 6-7, 2000, Sarasota, FL.

Dunning, R., and D. Sloan. n.d. *Aquaculture in North Carolina, Rainbow Trout: Inputs, Outputs, and Economics*. North Carolina Department of Agriculture and Consumer Services, Division of Aquaculture and Natural Resources, Franklin, NC.

Erickson, L.J. 1999. Personal communication with Mike Clipper (USEPA), April 20, 1999.

Eversole, A.G., and W. R. McClain. 2000. Crawfish Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 185-198. John Wiley and Sons, NY.

FDA (Food and Drug Administration). 2002. *Drugs Approved for Use in Aquaculture (Poikilothermic Food Species)*. <http://www.fda.gov/cvm/index/aquaculture/appendixa6.htm>. Accessed March 2002.

Fish Farming News. 2000. Water Reuse Key to Future of Texas Shrimp Farming. *Fish Farming News* (January/February).

Fitzpatrick, M.S, W.M. Contreras-Sanchez, and C.B. Schreck. 2000. *Fate of Methyltestosterone in the Pond Environment: Detection of MT in Soil After Treatment with MT Food*. Pond Dynamics, Aquaculture CRSP, Corvallis, OR.

Francis-Floyd, R. 2000. Disease History of Cultured Sturgeon in Florida, 1990-1999. In *Proceedings of the Florida Sturgeon Culture Risk Assessment Workshop*, April 6-7, 2000, Sarasota, FL.

Friedland, K. 2000. *Status of Fisheries Resources off Northeastern United States—Atlantic and Shortnose Sturgeons*. <http://www.nefsc.nmfs.gov/sos/spsyn/af/sturgeon/>. Last revised January 2000. Accessed March 2002.

Gatlin, D.M., III. 2001. *Guidelines for Nutrition and Feeding of Striped Bass and Hybrids*. <http://www.aquafeed.com/sp_stbass1.html>. Accessed December 2002.

Government of British Columbia. n.d. *Conservation Fish Culture for White Sturgeon*. <http://www.bcfisheries.gov.bc.ca/fishhabitats/Sturgeon/Culture.htm>. Accessed March 2002.

Grace, G.R., and R.H. Piedrahita. 1994. Carbon Dioxide Control. In *Aquaculture Water Reuse Systems: Engineering Design and Management,* ed. M. B. Timmons and T. M. Losordo, pp. 209-234. Elsevier Science Publishing Company. Amsterdam, The Netherlands.

Gulf of Maine Aquarium. 2000. *All About Lobsters: Lobstering History*. Lobster History—Gulf of Maine Aquarium. <http://www.octupus.gma.org/lobsters/allaboutlobsters/lobsterhistory.html>. Accessed January 2002.

Gunderson J.L., and P. Tucker. 2000. *A White Paper on the Status of Needs of Baitfish Aquaculture in the North Central Region*. Draft document. North Central Regional Aquaculture Center, Lansing, MI.

Haamer, J. 1996. Improving Water Quality in a Eutrophied Fjord System with Mussel Farming. *Ambio* 25(5):356-362.

Hardy, R.W., G.C.G. Fornshell, and E.L. Brannon. 2000. Rainbow Trout Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 716-722. John Wiley and Sons, Inc., NY.

Harrell, R.M. 1997. *Morone* Pond Production. In *Striped Bass and Other Morone Culture: Developments in Aquaculture and Fisheries Science,* ed. R.M. Harell, vol. 30. pp. 75-97. Elsevier Science, Amsterdam, The Netherlands.

Harrell, R.M., and D.W. Webster. 1997. An Overview of *Morone* Culture. In *Striped Bass and Other Morone Culture: Developments in Aquaculture and Fisheries Science,* ed. R.M. Harell, vol. 30. pp. 1-10. Elsevier Science, Amsterdam, The Netherlands.

Hartman, K.J., and B. Preston. 2001. Stocking. pp 661-686. In *Fish Hatchery Management*, 2d ed. G.A. Wedemeyer, ed. American Fisheries Society, Bethesda, MD.

Heidinger, R. 2000. Black Bass/Largemouth Bass Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 108-117. John Wiley and Sons, Inc. NY.

Heykoop, J., and D. Freschette. 1999. A Dynamic Model of the U.S. Alligator Industry: Lessons for Sustainable Use and Farm Management. In *Proceedings from the American Agricultural Economics Association Annual Meeting*, Nashville, TN, August 8-11, 1999.

Hinshaw, J.M. 2000. *Trout Farming: Carrying Capacity and Inventory Management*. SRAC publication no. 222. Southern Regional Aquaculture Center, Stoneville, MS.

Hochheimer, J.N., and F.W. Wheaton. 1997. Intensive Culture of Striped Bass. In *Striped Bass and Other Morone Culture: Developments in Aquaculture and Fisheries Science,* ed. R.M. Harell, vol. 30. pp. 127-168. Elsevier Science, Amsterdam, The Netherlands.

Hodgkins, H. 2002. Executive Secretary Maine Lobster Pound Association, Orono, ME. Personal communication, January 23, 2002.

Holt, G.J. 2000. Ornamental Fish Culture, Marine. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 610-614. John Wiley and Sons, Inc., NY.

Hopkins, J.S., R.D. Hamilton, P.A. Sandifer, C.L. Browdy, and A.D. Stokes. 1993. Effect of Water Exchange Rate on Production, Water Quality, Effluent Characteristics and Nitrogen Budgets of Intensive Shrimp Ponds. *Journal of the World Aquaculture Society* 24(3):304-320.

Hopkins, J.S., A.D. Stokes, C.L. Browdy, and P.A. Sandifer. 1991. The Relationship Between Feeding Rate, Paddlewheel Aeration Rate and Expected Dawn Dissolved Oxygen in Intensive Shrimp Ponds. *Aquacultural Engineering* 10(1991):281-290.

Howell, W.H., and M. K. Litvak. 2000. Winter Flounder Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 998-1005. John Wiley and Sons, Inc., NY.

IDEQ (Idaho Department of Environmental Quality). n.d. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

Illinois-Indiana Sea Grant. n.d. *Sea Grant Tip Sheet Series AS-508*. <http://www.aquanic.org/publicat/state/il-in/as-508.htm.> Accessed March 2002.

Imperial Irrigation District. 1998. *Aquatic Weed Control.* <http://www.iid.com/aboutiid/env-weed.html>. Accessed March 2002.

Iversen, E.S., D.M. Allen, and J.B. Higman. 1993. *Shrimp Capture and Culture Fisheries in the United States*. Halsted Press, an Imprint of John Wiley and Sons, Inc., NY.

Jensen, G. 2000. U.S. Department of Agriculture, Washington DC. Personal communication with Marta Jordan (USEPA), December 12, 2000.

Jensen, J. 1989. *Watershed Fish Production Ponds: Site Selection and Construction*, SRAC publication no. 102. Southern Regional Aquaculture Center, Stoneville, MS.

JSA (Joint Subcommittee on Aquaculture). 2000a. *Effluents from Catfish Aquaculture Ponds*. Prepared by the Technical Subgroup for Catfish Production in Ponds, Joint Subcommittee on Aquaculture, Washington, DC.

JSA (Joint Subcommittee on Aquaculture). 2000b. *Comments submitted to EPA in response to Industry Profile Draft: Ornamental Fish,* Washington, DC.

JSA (Joint Subcommittee on Aquaculture). 2000c. *Comments submitted to EPA in response to Industry Profile Draft: Molluscan Shellfish*, Washington, DC.

Karlsen, L. 1993. Chapter 3: Developments in Salmon Aquaculture Technology. pp. 59-82. In *Salmon Aquaculture*. eds. K. Heen, R.L. Monahan, and F. Utter. Halsted Press, New York, NY.

Kendra, W. 1991. Quality of Salmon Hatchery Effluents During a Summer Low-Flow Season. *Transactions of the American Fisheries Society* 120:43-51.

KSU (Kentucky State University). 2002. *Shrimp Manual*. Kentucky State University Aquaculture Program. <http://www.ksuaquaculture.org/ShrimpManual %20text%20Apr.pdf>. Accessed May 2002.

Kohler, C.C. 2000a. Striped Bass and Hybrid Striped Bass Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 898–907. John Wiley and Sons, Inc., NY.

Kohler, C.C. 2000b. *A White Paper on the Status and Needs of Tilapia Aquaculture in the North Central Region*. North Central Regional Aquaculture Center, Lansing, MI.

Kraeuter, J., B. Dewey, and M. Rice. 2000. *Preliminary Response to EPA's Aquaculture Industry Regulatory Development Data Needs*. Joint Subcommittee on Aquaculture, Molluscan Shellfish Aquaculture Technical Subgroup, Washington, DC.

KSUAP (Kentucky State University Aquaculture Program.) n.d. Perca flavescens: *Yellow Perch*. <http://www.ksuaquaculture.org/fish.yperch.htm>. Accessed March 2002.

Lane, T.J., and F.W. King. 1996. *Alligator Production in Florida*. VM-52. Department of Large Animal Clinical Services, College of Veterinary Medicine, Florida Cooperative Extension Service, University of Florida, Gainesville, FL.

Lawson, T. 1995a. Raceway Culture Systems. pp. 176-179. In *Fundamentals of Aquacultural Engineering*. Chapman & Hall, New York, NY.

Lawson, T. 1995b. Water Supply. pp. 48-57. In *Fundamentals of Aquacultural Engineering*. Chapman & Hall, New York, NY.

Lawson, T. 1995c. Oxygen and Aeration. pp. 248-310. In *Fundamentals of Aquacultural Engineering*. Chapman & Hall, New York, NY.

Lobster Institute. 1995, October 18. *Lobster Pound*. Lobster Pound—University of Maine. <http://www.lobster.um.maine.edu/lobster/library/publications/lobsterpound/lobsterpound.html>. Accessed November 2001.

Loughlin, M., R. Bayer, D. Prince, T. Axford, and H. Hodgkins. 2000, October. *Lobster Pound Manual*. The Lobster Institute and the Maine Agricultural and Forest Experiment Station at the University of Maine, Orono, ME.

Loyless, J.C., and R.F. Malone. 1997. A Sodium Bicarbonate Dosing Methodology for pH Management in Freshwater-Recirculating Aquaculture Systems. *The Progressive Fish-Culturist* 59:198-205.

Loyless J.C., and R.F. Malone. 1998. Evaluation of Airlift Pump Capabilities for Water Delivery, Aeration, and Degasification for Application to Recirculating Aquaculture Systems. *Aquacultural Engineering* 18:117-133.

LSU (Louisiana State University). 1999. *Crawfish Production Manual*. Publication no. 2637. Louisiana State University, Agricultural Center, Louisiana Cooperative Extension Service, Baton Rouge, LA.

Maine. 2002. *Maine Landing Statistics for 2000*. Maine Department of Marine Resources. <http://www.state.me.us/dmr/Comfish/maine_2000_landing_statistics.htm>. Accessed January 2002.

Malone, R.F., and L.E. Beecher. 2000. Use of Floating Bead Filters to Recondition Recirculating Waters in Warmwater Aquaculture Production Systems. *Aquacultural Engineering* 22(1-2):33-56.

Manci, B. 2000. Prospects for Yellow Perch Aquaculture. *Global Aquaculture Advocate* 3(6):62-63.

Masser, M.P. 1993a. *Alligator Production: Breeding and Egg Incubation*. SRAC publication no. 231. Southern Regional Aquaculture Center, Stoneville, MS.

Masser, M.P. 1993b. *Alligator Production: Growout and Harvest*. SRAC publication no. 232. Southern Regional Aquaculture Center, Stoneville, MS.

Masser, M.P. 2000. Alligator Aquaculture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 27-33. John Wiley and Sons, Inc., NY.

McGee, M.V., and C. E. Boyd. 1983. Evaluation of the Influence of Water Exchange in Channel Catfish Ponds. *Transactions of the American Fisheries Society* 112:557-560.

Meronek, T.G., F.A. Copes, and D.W. Coble. 1997. *The Bait Industry in Illinois, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin*. Technical bulletin series 105. North Central Regional Aquaculture Center, Lansing, MI.

Mims, S.D., W.L. Shelton, F.S. Wynne, and R.J. Onders. 1999, November. *Production of Paddlefish*. SRAC publication no. 437. Southern Regional Aquaculture Center, Stoneville, MS.

Nash, C., ed. 2001, September. *The Net-Pen Salmon Farming Industry in the Pacific Northwest.* NOAA Technical Memorandum NMFS-NWFS-49.

Newell, R.I.E., and J.A. Ott. 1999. Macrobenthic Communities and Eutrophication. pp. 265–293. In Ecosystems at the Land-Sea Margin: Drainage Basin to Coastal Sea. eds. T. Malone, A. Malej, L. Harding, N. Smodlaka, and R. Turner, *Coastal and Estuarine Studies* 55, American Geophysical Union.

Novotny, A.J., and W. Pennell. 1996. Rearing Salmonids to Market Size in Marine Waters. In *Principles of Salmonid Culture*, ed. W. Pennell and B.A. Burton, pp. 569-611. Elsevier Science, Amsterdam, The Netherlands.

Papoutsoglou, S.E., and G. Tziha. 1996. Blue Tilapia (Oreochromis aureus) Growth Rate in Relation to Dissolved Oxygen Concentrations Under Recirculating Water Conditions. *Aquacultural Engineering* 15. 181-192.

Pardue, J.H., R.D. DeLaune, W.H. Patrick, Jr., and J.A. Nyman. 1994. Treatment of Alligator Farm Wastewater Using Land Application. *Aquacultural Engineering* 13:129–145.

Parker, N.C. 1981. An Air-Operated Fish Culture System with Water-Reuse and Subsurface Silo, pp. 131–137. In *Proceedings of the Bioengineering Symposium for Fish Culture*, Vol. 1.

Parker, N.C., and M.A. Suttle. 1987. Design of Airlift Pumps for Water Circulation and Aeration in Aquaculture. *Aquacultural Engineering* 6:97–110.

Pennell, W., and W.E. McLean. 1996. Early Rearing. In *Principles of Salmonid Culture*, ed. W. Pennell and B. A. Burton, pp. 365–465. Elsevier Science, Amsterdam, The Netherlands.

Pennell, W., E.D. Lane, and F. Dalziel. 2001. Open Systems: The Culture of Fish for Release into Natural Systems. pp. 187–239. In *Fish Hatchery Management*, 2d ed. G.A. Wedemeyer, ed. American Fisheries Society, Bethesda, MD.

Pepper, V.A., and L.W. Crim. 1996. Broodstock Management. In *Principles of Salmonid Culture*, ed. W. Pennell and B.A. Burton, pp. 231–289. Elsevier Science, Amsterdam, The Netherlands.

Piper, R., I. McElwain, L. Orme, J. McCraren, L. Fowler, and J. Leonard. 1982. *Fish Hatchery Management*. U.S. Fish Department of the Interior, Fish and Wildlife Service, Washington, DC.

Plumb, J.A. 1994a. *Health Maintenance of Cultured Fishes: Principal Microbial Diseases*. pp. 49–55. CRC Press, Boca Raton, FL.

Plumb, J.A. 1994b. *Health Maintenance of Cultured Fishes: Principal Microbial Diseases*. pp. 135–160. CRC Press, Boca Raton, FL.

Plumb, J.A. 1994c. *Health Maintenance of Cultured Fishes: Principal Microbial Diseases*. pp. 177–222. CRC Press, Boca Raton, FL.

Plumb, J.A. 1997. Infectious Diseases of Striped Bass. In *Striped Bass and Other Morone Culture: Developments in Aquaculture and Fisheries Science*, ed. R.M. Harell, vol. 30. pp. 271–313. Elsevier Science, Amsterdam, The Netherlands.

Popma, T., and M. Masser. 1999. *Tilapia: Life History and Biolog*y. SRAC publication no. 283. Southern Regional Aquaculture Center, Stoneville, MS.

PSMFC (Pacific States Marine Fisheries Commission). 1996. *White Sturgeon. (Fact sheet)*. Revised December 12, 1996. <http://www.psmfc.org/habitat /edu_wsturg_fact.html>. Accessed March 2002.

Radonski, G.C., and R.G. Martin. 1986. Fish Culture is a too, not a Panacea. pp. 7–13. In *Fish Culture in Fisheries Management*. R.H. Stroud, ed. American Fisheries Society, Bethesda, MD.

Rakocy, J.E. 1989. *Tank Culture of Tilapia*. SRAC publication no. 282. Southern Regional Aquaculture Center, Stoneville, MS.

Rakocy, J.E., and A.S McGinty. 1989. *Cage Culture of Tilapia*. SRAC publication no. 281. Southern Regional Aquaculture Center, Stoneville, MS.

Reinemann, D.J., and M.B. Timmons. 1989. Prediction of Oxygen Transfer and Total Dissolved Gas Pressure in Airlift Pumping. *Aquaculture Engineering* 8:29–46.

Revkin, A.C. 1999, June 24. Making Up Their Beds and Hoping the Oysters Will Move In. *New York Times*.

Rice, M.A., A. Valliere, M. Gibson, and A. Ganz. 1999. Eutrophication Control by Bivalves: Population Filtration, Sedimentation and Nutrient Removal Through Secondary Production. (Abstract). *Journal of Shellfish Research* 18:333.

Roberts, R.J., and R.W. Hardy. 2000. Salmon Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 773–778. John Wiley and Sons, Inc., NY.

Rodhouse, P.G., and C.M. Roden. 1987. Carbon Budget for Coastal Inlet in Relation to Intensive Cultivation of Suspension-Feeding Bivalve Molluscs. *Marine Ecology Progress Series* 36:225–236.

SAIC (Science Applications International Corporation). 1998. *Final Report: Best Conventional Pollutant Control Technology and/or Best Available Technology to Support Economically Achievable Effluent Limitations for Shrimp Farm Operations*. Submitted to U.S. Environmental Protection Agency by Science Applications International Corporation, San Diego, CA.

Sastry B.N., A.A. Delos Reyes, Jr., K.A. Rusch, and R.F. Malone. 1999. Nitrification Performance of a Bubble-Washed Bead Filter for Combined Solids Removal and Biological Filtration in a Recirculating Aquaculture System. *Aquacultural Engineering* 19:105–117.

Schaeffer, D.O. 1990. Preventing Bacteria Disease Problems in Farm Raised Alligators. *Gator Tales* 1(1):5–6. (Louisiana Alligator Farmers and Ranchers newsletter).

Schramm, H.L., Jr., and R.G. Piper, eds. 1995. Uses and Effects of Cultured Fishes in Aquatic Ecosystems. American Fisheries Society Symposium 15, Bethesda, MD.

Schwartz, M.F., and C.E. Boyd. 1994a. Effluent Quality During Harvest of Channel Catfish from Watershed Ponds. *Progressive-Fish Culturist* 56:25–32.

Schwartz, M.F., and C.E. Boyd. 1994b. Channel Catfish Pond Effluents. *Progressive Fish-Culturist* 56:273–281.

Seok, K., S. Leonard, C.E. Boyd, and M.F. Schwartz. 1995. Water Quality in Annually Drained and Undrained Channel Catfish Ponds over a Three-Year Period. *Progressive Fish-Culturist* 57:52–58.

Smith, B.W., and W.C. Reeves. 1986. Stocking Warmwater Species to Restore and Enhance Fisheries. pp 17–29. In *Fish Culture in Fisheries Management*. R.H. Stroud, ed. American Fisheries, Bethesda, MD.

SRAC (Southern Regional Aquaculture Center). 1998. *Improving Feeds for Hybrid Striped Bass*. SRAC publication no. 304. Southern Regional Aquaculture Center, Stoneville, MS.

Stickney, R.R. 2000a. Carp Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 147–153. John Wiley and Sons, Inc., NY.

Stickney, R.R. 2000b. History of Aquaculture. In *Encyclopedia of Aquaculture*. ed. R.R. Stickney, pp. 436–446. John Wiley and Sons, Inc., NY.

Stickney, R.R. 2000c. Tilapia Culture. In *Encyclopedia of Aquaculture*, ed., R.R. Stickney, pp. 934–941. John Wiley and Sons, Inc., NY.

Stickney, R.R. 2000d. Cage Culture. In *Encyclopedia of Aquaculture*, ed., R.R. Stickney, pp. 139–141. John Wiley and Sons, Inc., NY.

Stone, N. 2000. Baitfish Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 97–104. John Wiley and Sons, Inc., NY.

Stone, N., and E. Park. 2001. University of Arkansas and Arkansas Baitfish Association. Personal communication, August, 1, 2001.

Stone, N., H. Thomforde, and E. Park. n.d. *Baitfish Production in Ponds*. Prepared for U.S. Environmental Protection Agency by the Technical Subgroup of the Joint Subcommittee on Aquaculture, Aquaculture Effluent Task Force, Washington, DC.

Stone, N., E. Park, L. Dorman, and H. Thomforde. 1997. *Baitfish Culture in Arkansas: Golden Shiners, Goldfish, and Fathead Minnows*. MP 386. Cooperative Extension Program, University of Arkansas at Pine Bluff.

Stoskopf, M.K. 1993. *Fish Medicine*. W.B. Saunders Company, Philadelphia, PA.

Sullivan, C.V., D.L. Berlinsky, and R.G. Hodson. 1997. Reproduction. In *Striped Bass and Other Morone Culture: Developments in Aquaculture and Fisheries Science,* ed. R.M. Harell, vol. 30. pp. 11–73. Elsevier Science, Amsterdam, The Netherlands.

Summerfelt, R.C. 2000. Walleye culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 970–985. John Wiley and Sons, Inc., NY.

Summerfelt, R.C., ed. 1996. *Walleye Culture Manual*, NCARC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames, IA.

Teichert-Coddington, D.R., D.B. Rouse, A. Potts, and C.E. Boyd. 1999. Treatment of Harvest Discharge from Intensive Shrimp Ponds by Settling. *Aquacultural Engineering* 19:147–161.

Tetra Tech, Inc. 2001. Technical Memorandum: Summary of Molluscan Shellfish Conference Call and Follow-Up. Tetra Tech, Inc., Fairfax, VA.

Tetra Tech, Inc. 2002a, August. Site visit report for Cantrell Creek Trout Farm, Brevard, NC.

Tetra Tech, Inc. 2002b, August. Site visit report for Clear Springs Foods, Inc., Box Canyon Facility, Buhl, ID.

Tetra Tech, Inc. 2002c, August. Site visit report for Lake Wheeler Road Agricultural Facility, Raleigh, NC.

Tetra Tech, Inc. 2002d, August. Site visit report for Aubrey Onley Aquaculture, Hertford, NC.

Tetra Tech, Inc. 2002e, August. Site visit report for DB Rice Fisheries, Birch Harbor, ME.

Tidwell, J.H., S.D. Coyle, and T.A. Woods. 2000. *Species Profile: Largemouth Bass*. SRAC publication no. 722. Southern Regional Aquaculture Center, Stoneville, MS.

Tomasso, J.R. 2002. Global Aquaculture Production with an Emphasis on the United States. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 1–7. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Treece, G. 2000. Shrimp Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 798–868. John Wiley and Sons, Inc., NY.

Tucker, C.S. 1996. The Ecology of Channel Catfish Ponds in Northwest Mississippi. *Reviews in Fisheries Science* 49(1):1–55.

Tucker, C.S., ed. 1998. *Characterization and Management of Effluents from Aquaculture Ponds in the Southern United States*. SRAC final report no. 600. Southern Regional Aquaculture Center, Stoneville, MS.

Tucker, C.S. 2000. Channel Catfish Culture. In *the Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp.153–170. John Wiley and Sons, Inc., NY.

Tucker, C.S., and J.A. Hargreaves. 1998. *Effluents from Channel Catfish Aquaculture Ponds*. Thad Cochran National Warmwater Aquaculture Center, Mississippi State University, Stoneville, MS.

Tucker, C.S., S.W. Kingsbury, J.W. Pote, and C.W. Wax. 1996. Effects of Water Management Practices on Discharge of Nutrients and Organic Matter from Channel Catfish Ponds. *Aquaculture* 147:57–69.

Tucker, C.S., and E.H. Robinson. 1990. *Channel Catfish Farming Handbook*. Van Nostrand, Reinhold, NY.

Tucker, C.S., and M. van der Ploeg. 1993. Seasonal Changes in Water Quality in Commercial Channel Catfish Ponds in Mississippi. *Journal of the World Aquaculture Society* 24(4): 473–481.

Tucker, C.S., C.E. Boyd, and J.A. Hargreaves. 2002. Characterization and Management of Effluents from Warmwater Aquaculture Ponds. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 35–76. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

USDA (U.S. Department of Agriculture). 1995. *Overview of Aquaculture in the United States*. U.S. Department of Agriculture, Animal and Plant Health Information Services, Centers for Epidemiology and Animal Health, Fort Collins, CO.

USDA (U.S. Department of Agriculture). 1997. *Catfish NAHMS '97, Part II: Reference of 1996 U.S. Catfish Management Practices*. Centers for Epidemiology and Animal Health, USDA/APHIS, Fort Collins, CO.

USDA (U.S. Department of Agriculture). 2000. *The 1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agriculture Statistics Service, Washington, DC.

USDA (U.S. Department of Agriculture). 2001. *Aquaculture Outloo*k. U.S. Department of Agriculture, Economic Research Service, Washington, DC.

USDA (U.S. Department of Agriculture). 2002, February 7. *Catfish Production.* U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002. National Pollutant Discharge Elimination System Permit no. ME0036234, issued to Acadia Aquaculture, Inc. Signed February 21, 2002.

Wallat, G., and L. Tiu. 1999. *Production and Feed Training of Yellow Perch Fingerlings*. The Ohio State University, Centers at Piketon, Piketon, OH.

Watson, C.A. 2002. University of Florida. Personal communication, February 2, 2002.

Watson, C.A., and J.V. Shireman. n.d. *Production of Ornamental Aquarium Fish*. Fact Sheet FA-35. University of Florida, Cooperative Extension Service, Gainesville, FL.

WDF (Washington Department of Fisheries). 1990. *Final Programmatic Environmental Impact Statement, Fish Culture in Floating Net-Pens*. Washington Department of Fisheries, Olympia, WA.

Weber, M.L. 1997. *Farming Salmon: Briefing Book*. The Consultative Group on Biological Diversity, San Francisco, CA.

Wellborn, T., and M. Brunson. 1997. *Construction of Levee-type Ponds for Fish Production,* SRAC publication no. 101. Southern Regional Aquaculture Center, Stoneville, MS.

Westat. 2002. *AAP Screener Survey Production Range Report, Revision IV*. Westat, Inc., Rockville, MD.

Westers, H. 2001. Production. In *Fishery Hatchery Management,* 2d ed., ed. G.A. Wedemeyer, pp. 31–90. American Fisheries Society, Bethesda, MD.

Weston, D. 1986, August. *The Environmental Effects of Floating Mariculture in Puget Sound*. Prepared for the Washington State Department of Fisheries and the Washington State Department of Ecology, Seattle, WA.

Weston, D. 1992. Status of Waste Management Practices in Marine Net-Pen Systems in Washington State. In *National Livestock, Poultry, and Aquaculture Waste Management*, ed. J. Blake, J. Donald, and W. Magette, pp. 211–214. publication no. 03-92. American Society of Agricultural Engineers, St. Joseph, MI.

Wikfors, G.H. 1999. Personal communication to Tim Motte, Coastal Resources Management Council. Cited in JSA (Joint Subcommittee on Aquaculture), Comments Submitted to EPA in Response to Draft Industry Profile: Molluscan Shellfish.

Winton, J.R. 2001. Fish Health Management. In *Fish Hatchery Management,* 2d ed., ed. G. Wedemeyer. American Fisheries Society, Bethesda, MD.

Zimmerman, T. 1998. How to Revive the Chesapeake Bay: Filter it with Billions and Billions of Oysters. *U.S. News & World Report*, December 29, 1997– January 5, 1998.

CHAPTER 5
INDUSTRY SUBCATEGORIZATION FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS

The Clean Water Act (CWA) requires EPA, when developing effluent limitations guidelines, to consider a number of different factors. For example, when developing limitations that represent the best available technology economically achievable (BAT) for a particular industry category, EPA must consider, among other factors, the age of the equipment and facilities in the category, location, manufacturing processes employed, types of treatment technology to reduce effluent discharges, cost of effluent reductions, and non-water quality environmental impacts (Section 304(b)(2)(B) of the CWA, 33 U.S.C. 1314(b)(2)(B)). The statute also authorizes EPA to take into account other factors that the EPA Administrator deems appropriate and requires the BAT model technology chosen by EPA to be economically achievable, which generally involves considering both compliance costs and the overall financial condition of the industry. EPA used the best available data to take these factors into account in considering whether to establish subcategories. The Agency found that dividing the industry into subcategories leads to better-tailored regulatory standards, thereby increasing regulatory predictability and diminishing the need to address variations among facilities through a variance process. (See *Weyerhaeuser Co*. v. *Costle*, 590 F. 2d 1011, 1053 (D.C. Cir. 1978) for more detail.)

5.1 FACTOR ANALYSIS

EPA used published literature, site visit data, industry screener survey data, and EPA sampling data for the subcategorization analysis. Various subcategorization criteria were analyzed for trends in discharge flow rates, pollutant concentrations, and treatability to determine where subcategorization (segmentation) was warranted. EPA analyzed several factors to determine whether subcategorizing an industrial category and considering different technology options for those subcategories would be appropriate. For this analysis, EPA evaluated the characteristics of the industrial category to determine their potential to provide the Agency with a means to differentiate effluent quantity and quality among facilities. EPA also evaluated the design, process, and operational characteristics of the different industry segments to determine technology control options that might be applied to reduce effluent quantity and improve effluent quality. The factors associated with the aquatic animal production (AAP) industry that EPA assessed for the concentrated aquatic animal production (CAAP) point source category are as follows:

- Species system type
- Facility age
- Facility location

- Facility size
- Feed type and feeding rate
- Non-water quality environmental impacts
- Disproportionate economic impacts

EPA found the AAP industry is very diverse and that there are many unique aspects, depending on a combination of the facility characteristics listed above. Although most of the individual facilities in the AAP industry tend to have unique design and operational characteristics, EPA found that one factor, system type, captures the dominant differences between significant groups of AAP facilities. The following sections show the basis for EPA's current decisions relating to subcategorization.

5.1.1 System Type

There are six groups of AAP systems: ponds, flow-through systems, recirculating systems, net pens, bottom and off-bottom shellfish culture, and other systems.

5.1.1.1 Pond Systems

Ponds are the most popular systems used to produce aquatic animals in the United States, with more than 2,800 commercial pond facilities (USDA, 2000) and numerous noncommercial ponds. Catfish, hybrid striped bass, shrimp, sport and game fish, ornamentals, and baitfish are all grown in pond systems. Pond systems use relatively large volumes of static water to grow aquatic animals. Most ponds used for producing aquatic animals range in size from less than 1 ac to more than 10 ac and typically have average depths of 3.5 to 6 ft. Once full of water, the ponds remain static in terms of water movement until rainfall events, operators add water, or the ponds are drained for harvest or maintenance. Water might be added intentionally to make up for seepage or evaporative losses and to exchange water to maintain process water quality. Pond draining frequencies range from annually to every 10 years (or more). Ponds rely on natural processes to maintain water quality, using supplemental aeration (when necessary) and limiting the stocking density of the crop.

Most pond systems used for AAP are constructed to operate and function in the same general manner. Control of water entering the pond is the primary characteristic that distinguishes one type of pond system from another. Further subdividing pond systems into levee, watershed, and depression ponds accounts for most of these differences. Levee ponds are constructed by creating a dam or berm completely around an area of land. Soil is taken from the area to be enclosed to create the berms. Levee ponds are constructed above grade to give the operator almost complete control of water in the pond. Only rainwater falling directly onto the surface of the pond and the interior walls of the berms enters the pond without operator intervention. Pumping, or otherwise conveying, water from a surface water or groundwater source adds water to the pond.

Watershed ponds are constructed by creating a dam across a low-lying area of land to capture runoff during rainfall events. The pond can be shaped and a flat, sloping bottom created to make the watershed pond easy to manage for producing aquatic animals. Sizing the watershed to capture the right amount of water is a critical design feature of properly constructed watershed ponds. A general rule of thumb is about 10 ac of watershed for each 1 ac of pond. The key consideration is to capture enough rainfall and runoff to keep the pond full. Oversized contributing watersheds tend to add too much water to the pond and create excessive overflows, which are difficult to manage. Some watershed ponds are filled or topped off with well water in addition to the natural runoff.

Depression ponds are built similarly to levee ponds but are almost completely below grade. They are typically constructed in sandy soils to allow high groundwater tables to contribute water to the pond. To drain depression ponds, they must be pumped. Water levels are often difficult to control in depression ponds, so they are mostly constructed in areas of good-quality groundwater that is consistently near the surface.

Two sources of water are discharged from ponds—overflows during or following rainfall events and water from intentional draining for harvest or renovation. Many ponds are managed to capture as much rainfall (and runoff in the case of watershed ponds) as possible to minimize the need for pumping water to maintain water levels. Overflows sometimes occur. Because levee ponds are built above grade, the only source of overflow during storms is the rain actually falling onto the surface of the pond and interior berms. This contrasts to watershed ponds, where larger areas can contribute to the volume of storm water entering and possibly overflowing from ponds. These overflows are intermittent, depending on the frequency and intensity of storms and the capacity of the pond for storing additional water. Many watershed ponds serve as a sink for pollutants (primarily sediment) entering the ponds in the runoff water. The overflows typically contain dilute concentrations of pollutants.

Discharges from ponds also occur when the ponds are drained as part of the management strategy for the operation. Two predominant drainage strategies have been found among pond facilities—annual (or more frequent) draining and less frequent-than-annual draining. Annual draining is common among many parts of the AAP industry, including fingerling production for most species and production of shrimp, baitfish, hybrid striped bass, and many other species of foodfish and sport fish. Some of these discharges might drain into adjacent ponds for storage and reuse. Less frequent-than-annual draining is used by segments of the industry that can selectively harvest and restock with smaller fish or can almost completely harvest and then kill any remaining fish before restocking. The desire is to minimize water usage and pumping costs. Both drainage strategies result in large, mostly dilute volumes of water being discharged over several days. Because water remains in the ponds for long periods of time, some natural processing of the wastes in the ponds occurs.

5.1.1.2 Flow-through Systems

Flow-through systems consist of raceways, ponds, or tanks that have constant flows of water through them. Flow-through systems are the second most popular production system in the United States, with more than 600 commercial and several hundred noncommercial facilities (USDA, 2000). Trout, salmon, and hybrid striped bass are examples of fish grown in flow-through systems. Flow-through systems are most commonly long, rectangular concrete raceways, but they also include tanks of various shapes made from fiberglass, concrete, or metal. Some flow-through systems use earthen ponds to culture aquatic animals.

In general, flow-through systems rely on flushing to maintain water quality, and the predominant management practices to maintain water quality are aeration, settling of solids in quiescent zones or in sumps, and maintenance of manageable stocking densities. Discharges from flow-through systems tend to be large in volume and continuous. When solids in tanks or raceways are collected and removed, these waste streams are usually higher in pollutant concentrations, including solids, nutrients, and biochemical oxygen demand than the water normally leaving the tank or raceway.

5.1.1.3 Recirculating Systems

Recirculating systems use a variety of processes to maintain production water quality and minimize water usage, including aeration, solids removal, biological filtration, and disinfection. Recirculating systems are gaining popularity in the United States as system design and management become better understood. Any species can be grown in a recirculating system, but tilapia and hybrid striped bass are the predominant species. The primary sources of wastewater are solids removal equipment and overflow. Overflow water is generated when water is regularly added to the recirculating system. Solids are captured from the production water and discharged in a waste stream that is relatively low in volume and high in pollutant concentrations. The solids generated from flow-through and recirculating systems are similar in quality.

5.1.1.4 Net Pens

A floating structure of nets can be used to contain fish in large water bodies, such as lakes, reservoirs, coastal waters, and the open ocean. The most significant net pen operations are salmon net pens located in the northeast and northwest coastal areas of the United States. Salmon are grown for foodfish and as a source of smolts for ocean ranching using net pens. Water quality is maintained in net pens by the flushing action of tides and currents. Feed is added in these operations.

5.1.1.5 Floating and Bottom Culture

Floating and bottom culture are used to grow molluscan shellfish in various coastal water environments. As in net pen culture, the flushing action of tides and currents helps to maintain water quality. Unlike fish produced in net pens, molluscan shellfish use naturally occurring food, the availability of which is also a function of the tides and currents. No feed is added to molluscan shellfish cultures in natural waters.

5.1.1.6 Other Facility Types

Other aquatic animal production facilities encompass those facilities that do not fit well into the other categories. Alligator farming is a good example. Alligator farming typically uses a batch cycling of water through the facilities. The water in cement-lined basins, located in huts, is replaced every few days. Water is held for as long as possible (to minimize energy needed to maintain the correct temperature) and then discharged. Alligator farms therefore produce intermittent flows of concentrated effluents. Another production type that does not fit well into the other system type descriptions is the crawfish pond. Although somewhat similar in appearance to other pond systems, crawfish ponds are shallow (typically less than 18 in. of water) and also managed for the forage crop that provides food for the growing crawfish. Water levels in crawfish ponds are managed by annual draining to promote reproduction in the pond.

5.1.1.7 Summary

The characteristics that distinguish CAAP systems from each other are the relative amount of water used to produce a unit of product, the draining frequency, the general design of the facility, and the processes used to treat production water. Table 5.1-1 shows the relative amount of water used, the draining frequencies, and the processes used to treat water for some of the system types. Each of the above system types has similar water use and management strategies, which produce wastewater flow rates and quality that are similar. Ponds produce infrequent discharges of overflow and drained water.

Table 5.1-1. Comparison of Water Use, Frequency of Discharge, and Process for Maintaining Water Quality for CAAP Systems

System	*Water Use (lb/yr Production per gal/min)*[a]	*Draining Frequency*	*Water Quality Maintenance in System*
Ponds	2,453	Infrequent	Aeration, water exchange, natural physical, chemical, and biological processes
Flow-through Coldwater species Warmwater species	 8.3–81.0 16	Continuous	Aeration, water exchange
Recirculating Coldwater species Warmwater species	 1,335 32,543	Continuous	Clarifiers, biological filters, aerators
Net pen	N/A	N/A	Water exchange

[a]Adapted from Chen et al., 2002.

The quality of overflow water from ponds is typically equivalent to the quality in the pond, which must be sufficient for animal production. Drained water is similar to overflow water in quality but may contain elevated levels of solids and other pollutants at the beginning or end of the draining process. Flow-through systems produce a constant, high-volume quantity and nearly consistent quality effluent that is relatively low in pollutant concentrations. Changes in flow-through system effluent quality reflect changes in biomass and cleaning activities. Recirculating systems produce a small volume of effluent mostly made up of solids removed by process equipment in the system. Net pens and shellfish culture discharge directly into the waters where they reside. Aquatic animals grown in net pens are fed by operators. Shellfish rely on natural food in the water and are not fed any additional food. Alligator systems are managed to discharge once every few days to keep the systems clean. The effluent is small in volume with relatively high levels of pollutants such as solids, biochemical oxygen demand, and nutrients. Crawfish effluents are infrequent when ponds are drained.

5.1.2 Species

EPA evaluated species as possible subcategories. The Agency's analyses indicated that species is not a significant factor in determining differences in production system effluent characteristics. For example, Hargreaves, et al., (2002) noted, "The ecological processes that affect effluent volume and quality are the same in all warmwater aquaculture ponds, whether they are used to grow baitfish in Arkansas or hybrid striped bass in North Carolina." EPA found similar results for other species. The management practices for a particular species dictate stocking densities, feed types, feeding rates and frequencies, and the overall management strategy. Species, however, does not appear to be a major determinant in the quality or quantity of effluent from a production system.

5.1.3 Facility Age

Facility age does not appear to be a significant factor in the quality or quantity of effluents from AAP facilities of the same system type. EPA noted a range of facility ages during site visits. Important factors associated with facility age include the following:

- Newer facilities might be designed with equipment that enhances the production capabilities or ease of operation.
- Some older facilities might not have sufficient area for the installation of treatment technologies.
- Some older facilities might not be conducive to retrofits of technologies; for example, quiescent zones in raceways.

5.1.4 Facility Location

EPA did not find geographic location to be a significant factor in the determination of effluent quality. EPA was not able to find any geographic operational differences that occur in the CAAP industry to indicate significant differences in the quality of discharges.

5.1.5 Facility Size

EPA found facility size enables some operational economies of scale, but the Agency does not expect size to have a significant influence on effluent quality. EPA does expect that facility size will have a significant impact on the quantity of effluent. EPA evaluated facility size as a part of the economic analyses and found size to be an important determinant in the affordability of treatment options (see USEPA, 2002 for more information).

5.1.6 Feed Type and Feeding Rate

EPA found feed type and feeding rate to be important characteristics of CAAP facilities that identify differences in effluent quality. The following factors were evaluated:

- No food is added, as in the case of molluscan shellfish culture. Naturally occurring and created foods are the source of food for these species. Natural foods are produced by stimulating production with nutrients (fertilizers) and are used for larval diets for many species (e.g., catfish, hybrid striped bass, perch, and most sport fish) and as the primary diet for species like baitfish. The use of natural diets is primarily limited to pond systems, but natural diets are also used in some flow-through and recirculating systems.
- Prepared diets are used for the production of most species in CAAP facilities. These diets vary in the ingredients and relative proportions of fat, protein, and

carbohydrates. The formulation of a diet can significantly influence the digestibility and uptake for a particular species.

- Feeding rates are a function of species, stocking density, temperature, and water quality.

Management objectives are a significant factor in feeding strategies. For example, game fish, grown for stocking enhancement in natural waters, are cultured with different management objectives than foodfish of the same species.

5.1.7 Non-water Quality Environmental Impacts

EPA evaluated the effects of various non-water quality environmental impacts (see Chapter 11 of this document), including the following:

- Energy use
- Solid waste generation and disposal
- Air emissions

5.1.8 Disproportionate Economic Impacts

The economic analysis evaluated the potential for disproportionate economic impacts of the rulemaking on various segments of the industry (USEPA, 2002).

5.1.9 Summary of Initial Factor Analysis

EPA did not find that equipment and facility age and facility location significantly affect wastewater generation or wastewater characteristics; therefore, age and location were not used as a basis for subcategorization. An analysis of non-water quality environmental characteristics (e.g., solid waste and air emission effects) showed that these characteristics also did not constitute a basis for subcategorization.

Facility size (production rates) directly affects the effluent quality, particularly the quantity of pollutants in the effluent, and size was used as a basis for subcategorization because more stringent limitations would not be cost- effective for smaller aquatic animal production facilities. EPA also identified types of production systems (e.g., flow-through, recirculating, or net pen) as a determinative factor for subcategorization due to variations in quantity and quality of effluents and estimated pollutant loadings. Based on the results of an initial evaluation, EPA determined that using the production system and facility size most appropriately subcategorizes the CAAP industry.

5.2 PROPOSED CATEGORIES

In the proposed rule, EPA proposes limitations and conditions for three subcategories. Specifically, EPA proposes new limitations and standards for facilities in the following CAAP subcategories: medium and large flow-through systems, recirculating systems, and net pens. This proposal would not revise the existing definition of a CAAP as described in Chapters 1 and 2. EPA chose to further segment the subcategories with different limitations by facility size (the amount of aquatic animals they produce) because of economic impact considerations (USEPA, 2002).

Minimum facility sizes used in subcategorization are based either on the current NPDES definition of a CAAP or at a higher level of production based on economic impacts. The NPDES definition sets the frequency of discharge at 30 d and a minimum production level of 20,000 lb/yr for coldwater species (e.g., trout and salmon) and 100,000 lb/yr for warmwater species (e.g., catfish, hybrid striped bass, and shrimp). Facilities are grouped into production size ranges, based on the size ranges developed by USDA for the 1998 Aquaculture Census. The sizes are estimated from production levels, typically in pounds, and used average prices reported in the 1998 Aquaculture Census (USDA, 2000) to convert production to dollar levels. The production size categories used for analysis are National 3 ($50,000 to $99,999); National 4 ($100,000 to $499,999); National 5 ($500,000 to $999,999); and National 6 (more than $1,000,000) (Hochheimer, 2002).

The following is a more detailed description of each subcategory based on its production processes and wastewater characteristics.

5.2.1 Flow-through Systems

EPA proposes the medium flow-through system facility subcategorization scheme to require all facilities that produce 100,000 lb/yr or more, but less than 475,000 lb/yr, of aquatic animals to be regulated by the same production-based effluent limitations guidelines. EPA proposes the large flow-through system facility subcategorization scheme to require all facilities that produce 475,000 lb/yr or more of aquatic animals to be regulated by the same production-based effluent limitations guidelines.

5.2.2 Recirculating Systems

EPA proposes the recirculating system subcategorization scheme to require all facilities that produce more than 100,000 lb/yr of aquatic animals to be regulated by the same production-based effluent limitations guidelines.

5.2.3 Net Pen Systems

EPA proposes the net pen system subcategorization scheme to require all facilities that produce more than 100,000 lb/yr of aquatic animals to be regulated by the same production-based effluent limitations guidelines.

5.3 REFERENCES

Chen, S., S. Summerfelt, T. Losordo, and R. Malone. 2002. Recirculating Systems, Effluents, and Treatments. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 119-140. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Hargreaves, J.A., C.E. Boyd, and C.S. Tucker. 2002. Water Budgets for Aquaculture Production. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 9-34. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Hochheimer, J. 2002. Technical Memorandum: Production Categories from NASS Data. Tetra Tech Inc., Fairfax, VA.

USDA (U.S. Department of Agriculture). 2000. *The 1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agriculture Statistics Service, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002. *Economic and Environmental Impact Analysis of Proposed Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Industry Point Source Category*. EPA 821-R-02-015. U.S. Environmental Protection Agency, Washington, DC.

CHAPTER 6
WATER USE, WASTEWATER CHARACTERIZATION, AND POLLUTANTS OF CONCERN

6.1 WATER USE BY SYSTEM TYPE

The quantity of water required for aquatic animal production (AAP) depends on the type of production system and the facility's management practices. For AAP facilities, water is required to replace evaporative and seepage losses, to replenish oxygen, and to flush wastes from the system. Most AAP facilities are constructed to allow the operators at least some control over the water supply to the production units. There are a wide array of production systems, many unique in their layout and design. The unique characteristics of an individual system often take advantage of site-specific water supply characteristics. The following subsections describe typical water use by production system type.

6.1.1 Pond Systems

The type of water supply for a pond system is primarily a function of the type of pond. Levee ponds are built with berms above grade to exclude surface water and allow the operator almost complete control of the water that enters the pond. Rainwater falling directly onto the surface of the pond and interior slopes of the berms is the only uncontrolled input of water to levee ponds; all other water is pumped or piped into the ponds.

Watershed ponds are constructed to capture water from a contributing watershed during storm events. Ideally, watershed ponds are constructed so that the contributing watershed provides good-quality water (free of sediment and other pollutants) and sufficient quantities of water to maintain adequate volumes throughout the year. The pond operator does not usually have much control over the runoff into the pond. Water is sometimes pumped or piped into watershed ponds to maintain pond volumes.

Depression ponds are constructed below grade, and most take advantage of groundwater seepage to maintain water levels in the pond. Depression ponds capture direct rainfall and some runoff, depending on the topography of the surrounding landscape. Water is sometimes pumped or piped into depression ponds to maintain pond volumes.

For many ponds the water supply is one or more wells located on-site at a facility. Some facilities rely on pumped or free-flowing water from surface water bodies such as lakes, streams, or coastal waters. Those relying on surface waters, however, must be careful not to introduce undesirable species or organisms into the culture ponds. To prevent this, water might need to be screened or filtered as it is pumped into the pond. Rainwater falling directly on the pond is also captured and can be a source for maintaining water levels, but most commercial aquaculture ponds cannot be filled with rainfall alone because rainfall events are sporadic.

Pond systems initially require a large supply of water to fill the ponds and then smaller amounts of water to regulate the water levels and compensate for seepage and evaporation. For example, a 10-ac pond with an average depth of 4 ft holds about 13 million gal of water. Adding 3 in. of water to compensate for evaporation requires about 815,000 gal of water in a 10-ac pond. Generally, ponds are drained infrequently; therefore, after initially filling the ponds, operators typically do not use large volumes of additional water. For those systems that rely on well water, water conservation and rainwater capture are important management tools to minimize pumping costs.

Pond system sizes vary depending on the species and lifestage (fingerlings versus food-size) raised and among facilities producing the same species. Typical pond sizes for catfish production vary from 7 to 15 ac of surface area and from 3 to 5 ft in depth (Hargreaves et al., 2002). Striped bass are cultured in ponds with an average size of 2 to 4 ac as fingerlings and then moved to growout ponds with 5 to 10 ac of surface area and a maximum depth of 6 ft (Hodson and Jarvis, 1990). Crawfish production ponds typically range in size from 10 to 20 ac (LSU, 1999).

Water use in pond systems varies based on the size and draining frequency of the pond. For example, a 10-ac catfish pond with a depth of 4 ft would contain about 13 million gal of water, but the water would be used for an average of 6 yr before being discharged (Boyd et al., 2000). Striped bass, shrimp, and crawfish production ponds are drained annually. Crawfish ponds usually are managed to contain about 8 to 10 in. of water, but water is exchanged throughout the harvest season (LSU, 1999). Water exchange can increase the water use in crawfish ponds to 651,800 gal/ac/yr (Lutz, 2001).

6.1.2 Flow-through Systems

Flow-through systems rely on a steady water supply to provide a continuous flow of water for production. The water is used to provide dissolved oxygen and to flush wastes from the system, which produces a high volume of continuous discharge. Most flow-through systems use well, spring, or stream water as a source of production water. These sources are chosen to provide a constant flow with relatively little variation in rate, temperature, or quality.

Sources of culture water for AAP facilities include groundwater, springs, surface water, rainwater, municipal water, and seawater (Lawson, 1995). Many of these water sources require either the filtration or purification of before use (Wheaton, 1977a). Common problems with source water include insufficient dissolved oxygen, heavy solids loads, and biological contaminates such as predator fish and insects.

Source water treatment systems are designed specifically to treat specific contaminates or problems with the source water before it is added to the culture system. Source water problems are usually specific to the water source. Groundwater lacks oxygen, but is usually free of other pollutants and therefore must only be aerated before use. Surface waters may contain one or more of a variety of contaminates including solids loads, wild fish, parasites, waterborne predators, and disease organisms. Surface waters are often filtered with fine mesh screens to remove these contaminates before use (Wheaton, 1977a).

Flow-through systems require high volumes of water. Water requirements for single-pass raceways can be as high as 30,000 to 42,000 gal/lb production; however, this requirement can be reduced to 6,600 gal/lb production using serial raceways (Hargreaves et al., 2002). Facilities with flow-through systems are found throughout the United States, wherever consistent quantity and quality of water are available. Flow-through systems are the primary method used to grow salmonid species such as rainbow trout. These species require high-quality cold water with high levels of dissolved oxygen. Flow-though systems are therefore located where water is abundant, allowing farmers to efficiently produce these types of fish.

6.1.3 Recirculating Systems

Recirculating systems do not require large volumes of water because the culture water is continuously filtered and reused before it is discharged. System water volumes include the volume of the production units, filters, and reservoirs. The production water treatment process is designed to minimize water requirements, which leads to small-volume, concentrated waste streams as well as makeup water overflow. Waste streams from recirculating systems are typically a small but continuous flowing effluent. (Refer to Chapter 4, section 4.2.3 for more information about internal treatment processes used in recirculating systems.) Facility operators typically rely on a supply of pumped groundwater from on-site wells or municipal water supplies. Most systems add makeup water (about 5% to 10% of the system volume each day) to dilute the production water and to account for evaporation, solids removal, and other losses. A recirculating production system operating at 10% added makeup water per day, would complete one water exchange every 10 d; a flow-through production system, on the other hand, might complete more than 100 volume exchanges per day (Orellana, 1992).

6.1.4 Net Pen Systems

Net pen systems rely on the water quality of the site at which the net pens are located. Open systems like net pen facilities can implement fewer practices than closed or semi-closed systems to control water quality parameters such as temperature, pH, and dissolved oxygen. Net pens and cages rely on tides and currents to provide a continual supply of high-quality water to the cultured animals and to flush wastes out of the system. The systems may be located along a shore or pier or may be anchored and floating offshore or in an embayment. Strict siting requirements typically restrict the number of units at a given site to ensure sufficient flushing to distribute wastes and prevent degradation of the bottom near the net pens.

6.1.5 Other Production Systems: Alligators

Alligator production systems use water primarily to provide resting pools and to clean the holding areas where alligators are kept. The amount of water used varies greatly between facilities depending on the cleaning frequency, pool depth, and water recirculating practices practiced at the facility. Water use estimates for the alligator industry varied between 0.5 gal and 2 gal per alligator per day (Pardue et al., 1994; Shirley, 2002, personal communication).

6.2 WASTEWATER CHARACTERISTICS

CAAP facilities produce a variety of pollutants that may be harmful to the aquatic environment when discharged in significant quantities. The most significant of these pollutants are nutrients (nitrogen and phosphorus), total suspended solids (TSS), and biochemical oxygen demand (BOD). Each of these pollutants causes a variety of impacts on water quality or ecology in different bodies of water. Each type of production system produces different quantities and qualities of effluents, which are determined by the following:

- Amount and type of feed used for production
- Volume and frequency of discharge
- In-system treatment processes (including natural processes)
- Other inputs to the process water (such as drugs or chemicals).

The following subsections describe some of the production system wastewater characteristics.

6.2.1 Pond Systems

Characteristics of effluent from pond systems are influenced by the culture practices used to raise different species and the type of pond used. The composition of pond effluents during water exchange, overflow after heavy rains, and initial stages of pond draining is similar to that of pond water (Boyd and Tucker, 1998). Pond systems are unique because they are capable of assimilating wastes within the pond. Over time, natural processes within the pond lower the concentrations of nitrogen, phosphorus, and organic material. If water is retained in catfish ponds over a long enough period of time, biological, chemical, and physical processes remove some of the waste generated by fish. Some of the organic matter from phytoplankton production and fish waste is oxidized in the natural process of microbial decomposition (JSA, 2000). Total nitrogen levels in catfish pond waters are lowered as nitrogen is lost from the water column as organic matter when nitrogen particulates decompose on the bottom of the pond. Nitrogen is also lost from the water as a gas through denitrification and volatilization. Finally, total phosphorus concentrations in the water are lowered as phosphorus is lost to the pond bottom soils as particulate organic phosphorus and precipitates of calcium phosphates.

6.2.1.1 Catfish

In catfish aquaculture ponds, the most important constituents of potential effluents are nitrogen, phosphorus, organic matter, and settleable solids (JSA, 2000). These materials are a direct or indirect product of feeds added to the ponds to promote rapid fish growth. Inorganic nutrients in fish waste stimulate the growth of phytoplankton, which, in turn, stimulate the production of more organic matter through photosynthesis. For both watershed and levee ponds, nitrogen and phosphorus compounds and organic matter are present in the pond water throughout the growout period, and they represent potential pollutants if discharged.

Table 6.2-1 shows effluent loadings for TSS, 5-day biochemical oxygen demand (BOD_5), total nitrogen (TN), and total phosphorus (TP) from channel catfish ponds in Alabama. These data illustrate the influence of draining frequency on annualized effluent loadings. For example, TSS loads from levee foodfish production ponds, which are drained an average of once per 6.5 yr, are about an order of magnitude lower than TSS loads from levee fry and fingerling ponds, which are drained once per year. Annual effluent loads in watershed ponds are about four times lower in the less frequently drained foodfish ponds than in fry and fingerling ponds.

Table 6.2-1. Mass Discharge of TSS, BOD_5, TN, and TP from Channel Catfish Farms in Alabama

Pond Type	*Source of Effluent*	*TSS (lb/ac/yr)*	*BOD_5 (lb/ac/yr)*	*TN (lb/ac/yr)*	*TP (lb/ac/yr)*
Fry and Fingerling Ponds Annual Draining					
Levee ponds	Overflow	58	7.9	4.5	0.48
	Partial drawdown	823	112.3	75.3	2.98
	Final drawdown	3,062	94.8	1.8	4.73
	Total	3,943	214.7	108.3	8.19
Watershed ponds	Overflow	232	31.5	9.82	1.94
	Partial drawdown	822	112.2	75.2	2.98
	Final drawdown	3,062	94.8	28.5	4.74
	Total	4,116	238.5	113.5	9.66
Foodfish Production Ponds Average 6 yr Between Drainings					
Levee ponds	Overflow	58	7.8	4.5	0.48
	Partial drawdown	123	16.9	6.1	0.45
	Final drawdown	204	6.3	19.0	0.31
	Total	385	31	29.6	1.24
Watershed ponds	Overflow	738	50.9	15.8	3.15
	Partial drawdown	123	16.9	6.1	0.45
	Final drawdown	204	6.3	19.0	0.31
	Total	1,065	74.1	40.9	3.91

Source: Boyd et al., 2000.

6.2.1.2 Hybrid Striped Bass

Effluents from hybrid striped bass ponds are similar to catfish pond effluents; however, hybrid striped bass facilities typcially drain their ponds more frequently because they must be drained and completely harvested before restocking. To avoid draining the ponds, some farmers treat the ponds with a piscicide (a pesticide, such as Rotenone, used to kill fish) to eliminate remaining fish before restocking. Ponds are usually drained annually or biennially, depending on stocking size and production management.

In a study in South Carolina (Tucker, 1998), water samples were collected and analyzed from 20 commercial hybrid striped bass ponds (Table 6.2-2). To provide a broad representation of the industry, researchers included large and small operations, as well as ponds from both the coastal plain and piedmont areas of the state. Most of the commercial ponds sampled were freshwater ponds, but some saltwater ponds were also represented in the study. Water samples were collected from the surface and the bottom of each pond. Overall, the quality of effluents from hybrid striped bass ponds varied greatly from pond to pond. Concentrations of suspended solids, TN (including total ammonia), and BOD were the parameters that were most elevated relative to the source water and could potentially have the greatest impact on receiving bodies of water.

Table 6.2-2. Means and Ranges for Selected Water Quality Variables from Hybrid Striped Bass Ponds in South Carolina

Variable	*Mean*	*Range*
Suspended solids (mg/L)	49	0–370
Volatile suspended solids (mg/L)	29	0–135
Biochemical oxygen demand (mg/L)	11.5	1.4–64.4
Kjeldahl nitrogen (mg/L)	7.1	0–97.0
Total ammonia (mg N/L)	0.95	0.02–7.29
Nitrite (mg N/L)	0.07	0–2.94
Nitrate (mg N/L)	0.36	0–4.61
Total phosphorus (mg P/L)	0.31	0–1.9
Soluble reactive phosphorus (mg P/L)	0.02	0–0.18

Source: Tucker, 1998.

6.2.1.3 Penaeid Shrimp

There is some evidence to suggest that effluent characteristics for marine shrimp ponds are similar to effluent characteristics for catfish farms (Table 6.2-3), but that the final portion of effluent from marine shrimp ponds is higher in pollutant concentrations by 20% to 30% (Boyd and Tucker, 1998). For example, total annual TSS for shrimp ponds is about 5,000 lb/ac and for catfish fingerling ponds about 4,000 lb/ac. When shrimp ponds are drained for harvest, the effluent is almost identical in composition to pond water until about 80% of the pond volume has been released (Boyd, 2000). During the draining of the final 20% of the pond volume, concentrations of BOD_5, TSS, and other substances increase because of sediment resuspension caused by harvest activities, crowding of agitated shrimp, and shallow and rapidly flowing water. The average BOD_5 and TSS concentrations often are about 50 mg/L and 1,000 mg/L, respectively (Boyd, 2000).

Although catfish ponds and shrimp ponds might have similar effluent characteristics, shrimp ponds are drained more frequently than food-size catfish ponds to facilitate harvest; therefore, the volume of water discharged from a shrimp farm is typically higher than the volume of water discharged from a catfish farm. Shrimp farms in the United States have responded to state regulatory concerns regarding the discharge of solids during draining and harvesting. In Texas, shrimp farms use drainage canals and large sedimentation basins to hold water on the farm and reuse the water in other ponds to minimize TSS in effluents. Most Texas facilities try to discharge during the winter, after harvests are complete and solids have had maximum time to settle (Tetra Tech, 2002).

Table 6.2-3. Average Concentrations and Loads of BOD_5 and TSS in a Typical Shrimp Farming Pond with a Water Exchange of 2% per day

Type of Effluent	*Concentration (mg/L)*		*Load (lb/ac)*	
	BOD_5	*TSS*	*BOD_5*	*TSS*
Water exchange	5	100	107	2,142
Draining (first 80%)	10	150	71	1,071
Final draining	50	1,000	89	1,785
Total	–	–	267	4,998

Source: Boyd, 2000.

South Carolina shrimp farmers also try to reuse water, when possible. Some South Carolina shrimp farms are holding water in harvested ponds and growing clams and other shellfish. The "treated" water is then slowly discharged after the shellfish are harvested (Whetstone, 2002 personal communication).

6.2.1.4 Other Species

Tilapia ponds are drained to harvest fish, to adjust fish inventories, or to repair ponds. At the start of pond draining for harvest, pond water effluent characteristics can be expected to be similar to production water characteristics. However, fish harvest by seining stirs up sediments at the bottom of the pond. In fertilized tilapia ponds, sediments are likely to contain significant quantities of nitrogen and phosphorus. As draining and seining continue, effluent water quality can be expected to deteriorate (Tucker, 1998).

Although there is little data on ornamental fish farm effluent characteristics in the literature, the impact from water discharged from ornamental fish production facilities is likely to be minimal. Assuming the average size of a growout pond is 2,152 ft^2 with approximately 80,000 gal of water, ornamental culture facilities typically discharge the volume of one pond, or less, per year (Watson, 2002 personal communication). There is also very little data available on water quality in commercial baitfish ponds or on effluents from these ponds. Baitfish production uses low biomass stocking densities. The combination of low biomass and reduced feed input before draining makes it likely that baitfish effluents will have lower solids concentrations than effluents from catfish ponds (Stone et al., n.d.).

There is limited information about the quality of water discharged from crawfish ponds for either rotational ponds or permanent ponds. Crawfish production relies on the forage-based system for feeding, so unlike other aquaculture production systems that rely on pelleted feed, feed management practices will not significantly affect water quality because the feed input is so low. Also, although dissolved oxygen levels are a concern, particularly as vegetation decays, crawfish farmers routinely check levels and use best management practices (BMPs) and technologies, such as mechanical aeration, to maintain appropriate dissolved oxygen levels. Very little data is available on water quality within commercial ponds for other finfish production or on effluents from these ponds; however, the effluent is likely to be similar to the effluent from hybrid striped bass ponds.

6.2.2 Flow-through Systems

Effluents from flow-through systems can be characterized as continuous, high-volume flows containing low pollutant concentrations. Effluents from flow-through systems are affected by whether a facility is in normal operation or whether the tanks or raceways are being cleaned. Waste levels can be considerably higher during cleaning events (Hinshaw and Fornshell, 2002; Kendra, 1991).

Boardman et al. (1998) conducted a study after surveys conducted in 1995 and 1996 by the Virginia Department of Environmental Quality (VDEQ) revealed that the benthic aquatic life of receiving waters was adversely affected by discharges from several freshwater trout farms. Three trout farms in Virginia were selected to represent fish farms throughout the state. This study was part of a larger project to identify practical treatment options that would improve water quality both within the facilities and in their discharges to receiving streams.

After initial sampling and documentation of facility practices, researchers and representatives from VDEQ discovered that although pollutants from the farms fell under permit regulation limits, adverse effects were still being observed in receiving waters. Each of the farms was monitored from September 1997 through April 1998, and water samples were measured for dissolved oxygen (DO), temperature, pH, settleable solids (SS), TSS, total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), 5-day biochemical oxygen demand (BOD_5), and dissolved organic carbon (DOC).

Sampling and monitoring at all three sites revealed that little change in water quality between influents and effluents occurred during normal conditions at each facility (Table 6.2-4). The average concentrations of each regulated parameter (DO, BOD_5, TSS, SS, and AN) were below their regulatory limit at each facility; however, raceway water quality declined during heavy facility activity like feeding, harvesting, and cleaning. During these activities, fish swimming rapidly or employees walking in the water would stir up solids that had settled to the bottom. During a 5-day intensive study, high TSS values were correlated with feeding events. TKN and ortho-phosphate (OP) concentrations also increased during feeding and harvesting activities. Overall, most samples taken during this study had relatively low solids concentrations, but high flows through these facilities increased the total mass loadings.

Table 6.2-4. Water Quality Data for Three Trout Farms in Virginia

Parameter	FARM A			FARM B			FARM C		
	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
Flow (mgd)	1.03–1.54[a] (*1.18*)[b]			4.26–9.43 (*6.39*)			9.74–10.99 (*10.54*)		
DO (mg/L)	9.2–14.2 (*10.6*)	3.2–13.3 (*7.0*)	5.7–9.5 (*8.5*)	8.2–11.5 (*10.5*)	5.8–10.8 (8.6)	6.8–9.6 (*7.9*)	9.4–10.6 (*10.5*)	4.8–9.7 (*7.6*)	7.2–9.4 (*8.1*)
Temp (ºC)	10.5–13 (*12.2*)	11.5–15 (*13*)	11–15.5 (*12.9*)	6–12.5 (*9.7*)	6–14 (*9.1*)	5–16.5 (*11.4*)	8.5–13.5 (*10.5*)	8–14 (*11.0*)	8.5–14 (*10.4*)
pH (SU)	7.1–7.4 (*7.3*)	7.0–7.4 (*7.2*)	7.3–7.8 (*7.5*)	7.3–7.6 (*7.5*)	7.2–7.6 (*7.4*)	6.9	7.3	7.1–7.6 (*7.3*)	7.8
TSS (mg/L)	0–1.1 (*0.2*)	0–30.4 (*3.9*)	0.8–6 (*3.2*)	0–1.8 (*0.5*)	0–43.7 (*5.3*)	1.5–7.5 (*3.9*)	0–1.5 (*0.3*)	0–28 (*7.1*)	4.1–62 (*6.1*)[c]
SS (mg/L)	0		0–0.04 (*0.02*)	0		0.01–0.08 (*0.04*)	0		0.04–0.08 (*0.07*)
BOD_5 (mg/L)	0–1.25 (*0.7*)	0.5–3.9 (*1.5*)	0.96–1.9 (*1.3*)	0–1.4 (*0.5*)	0.3–7.2 (*2.1*)	0.6–2.4 (*1.2*)	0–2.0 (*1.1*)	0.4–7.5 (*2.5*)	0.5–1.8 (*1.3*)
DOC (mg/L)	0.93–4.11 (*2.1*)	0.9–7.9 (*2.9*)	1.5–2.4 (*1.9*)	0.91–2.56 (*1.6*)	1.2–8.1 (*2.7*)	1.2–3.1 (*1.9*)	1.1–2.7 (*2.0*)	1.1–11.1 (*2.4*)	1.5–3.8 (*2.3*)
NH_3-N (mg/L)	0.6	0.2–1.1 (*0.5*)	0.5–0.6 (*0.6*)	0.2	0.06–1.1 (*0.5*)	0.45	0.03	0.03–2.2 (*0.4*)	0.02–0.17 (*0.1*)

[a] When available the range of values has been reported
[b] The average is indicated using italics.
[c] Two outliers were discarded for calculation of mean.
Source: Boardman et al., 1998.

Table 6.2-5 describes the water quality data for two flow-through systems sampled as part of EPA's data collection efforts at CAAP facilities.

Table 6.2-5. Flow-through Sampling Data Table

Parameter	Facility A			Facility B		
	Inlet	OLSB Effluent	Bulk Water Discharge	Inlet	OLSB Effluent	Final Effluent
Biochemical oxygen demand (mg/L)	ND (4)[a]	56.0–185.0[b] (*125.70*)[c]	3.50–4.20 (*3.85*)	ND (2)	13	ND (2)
Flow (mgd)	192.4	0.914	91.4	2.481–2.777	0.017	2.481–2.777
pH (SU)	7.98–8.14 (*8.05*)	6.11–6.58 (*6.43*)	7.50–7.83 (*7.72*)	7.73–8.06 (*7.93*)	7.27	7.93–8.19 (*8.03*)
Total phosphorus (mg/L)	0.7–0.25 (*0.14*)	8.32–11.10 (*9.81*)	0.15–0.25 (*0.21*)	0.02–0.03 (*0.03*)	0.36	0.03–0.07 (*0.05*)
Total suspended solids (mg/L)	ND (4)	44.0–78.0 (*63.0*)	ND (4)	ND (4)	38	ND (4)

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
Source: USEPA sampling data.

6.2.3 Recirculating Systems

Recirculating systems have internal water treatment components that process water continuously to remove waste and maintain adequate water quality. Overall, recirculating systems produce a lower volume of effluent than flow-through systems. The effluent from recirculating systems usually has a relatively high solids concentration in the form of sludge. The sludge is then processed into two streams—a more concentrated sludge and a less concentrated effluent (Chen et al., 2002). Once solids are removed from the system, sludge management is usually the focus of effluent treatment in recirculating systems.

In a study describing the waste treatment system for a large recirculating facility in North Carolina, Chen et al. (2002) characterize effluent at various points in the system (Table 6.2-6). Approximately 40% of the solid waste produced by this particular facility is collected in the sludge collector and composted. The remaining 60% of the solids are treated with two serial primary settlers (septic tanks) and then a polishing pond (receiving pond). Table 6.2-7 describes the water quality data for one recirculating system sampled as part of EPA's data collection efforts at CAAP facilities.

Table 6.2-6. Water Quality Characteristics of Effluent at Various Points in the Waste Treatment System of Recirculating Aquaculture Systems at the North Carolina State University Fish Barn[a]

Parameter	*TKN (mg/L)*	*NH_3-N (mg/L)*	*NO_2N (mg/L)*	*NO_3N (mg/L)*	*TP (mg/L)*	*PO_4-P (mg/L)*	*COD (mg/L)*	*TS (%)*	*TSS (mg/L)*
Primary settling 1 inflow	50.3	2.96	5.35	109.0	28.6	5.98	1043	0.22	752
Primary settling 2 inflow	47.5	2.42	31.17	78.5	22.7	11.50	690	0.18	364
Septic tank 2 outflow	37.7	3.42	44.00	36.4	17.6	12.20	409	0.16	205
Receiving pond effluent	8.94	0.12	1.93	8.2	4.95	3.68	153	0.11	44

[a] Results are from sampling conducted 4 wk after startup of the waste handling system. Flow from the system into the receiving pond for the sampling period was 15.5 m^3/d.
Source: Chen et al., 2002.

6.2.4 Net Pen Systems

Although net pen systems do not generate a waste stream like other production systems, waste from the system can adversely affect water quality. The release of nutrients, reductions in concentrations of dissolved oxygen, and the accumulation of sediments under the pens or cages can affect the local environment through eutrophication and degradation of benthic communities (Stickney, 2002).

Table 6.2-7. Recirculating System Sampling Data

Parameter	Facility C	
	Inlet	*Discharge*
Biochemical oxygen demand (mg/L)	ND (2)[a]	35.0–48.0[b] (*42.0*)[c]
Flow (mgd)	0.22	0.22
pH (SU)	7.8	6.97–7.25 (*7.15*)
Total phosphorus (mg/L)	ND (0.01)	8.58–10.50 (*9.32*)
Total suspended solids (mg/L)	ND (4)	26.0–60.0 (*42.80*)

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
Source: EPA sampling data.

6.2.5 Other Production Systems: Alligators

Wastewater from alligator production facilities is generated during the cleaning of production pens and when discharges are released from the building heating system. Wastewater characteristics from alligator farms are analogous to those of strong municipal wastewater (Pardue et al., 1994). Values for alligator farm wastewater constituents are shown in Table 6.2-8.

Table 6.2-8. Alligator Wastewater Characteristics

Parameter	*Concentration (mg/L)*
BOD_5	452
Total solids	379
Volatile solids	219
Total phosphorus	11
Ammonia (NH_3)	78
Nitrite (NO_3)	5
TKN	153
pH	6.9 (SU)

Source: Pardue et al., 1994.

6.3 Water Conservation Measures

6.3.1 Pond Systems

Pond systems provide many opportunities to conserve water. Water conservation practices can be grouped into structural conservation measures and management conservation measures. Structural conservation measures are those measures that can be installed at the time the production pond is constructed or added at a later date. Structural water conservation measures include seepage reduction, watershed-to-pond area ratios of 10 or less, and vegetated levees. Ongoing management water conservation measures include maintaining storage volume, harvesting without draining, and reducing or eliminating water flushing (Hargreaves et al., 2002).

6.3.2 Flow-through Systems

The opportunities to conserve water in flow-through systems are usually limited and can involve substantial expense. Often, more fish can be grown in a flow-through system with a fixed inflow of water through increased stocking densities in production raceways, with additional oxygenation of the production water. Water use can also be maximized through the use of multi-pass serial raceways or tanks, which use re-oxygenated water passing through multiple raising units prior to discharge. Using water more efficiently allows flow-through system operators to reduce water use from high rates of 30,000 to 42,000 gal/lb to much lower rates of 6,600 gal/lb.

Facilities reusing multi-pass serial raceways must use active or passive aeration systems in order to maintain adequate dissolved oxygen concentrations in the culture water. Facilities with sufficient hydraulic head between raceways often use passive or gravity aeration systems to increase the air-water interface thereby increasing the dissolved oxygen content of the culture water (Wheaton, 1977b).

Facilities with insufficient head to passively aerate must use mechanical aeration systems to increase the dissolved oxygen content of the culture water. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems operate by adding liquid oxygen below the surface of the culture water. Diffuser aerators inject air or pure oxygen below the culture waters surface in the form of bubbles. As the bubbles pass through the water column oxygen is transferred across the air-water interface (Wheaton, 1977b).

6.3.3 Recirculating Systems

Recirculating systems are designed to conserve water by raising fish in small volumes of water, treating the water to remove waste products, and then reusing it (Rakocy et al., 1992). Normal stocking densities in recirculating systems vary from 0.5 to over 1 lb per gallon of culture water (Losordo and Timmons, 1994). Opportunities to conserve water in recirculating systems include operating all filter systems as efficiently as possible, increasing stocking densities, and reducing daily makeup water to below 10%. These practices would not amount to significant reductions in water use and might not be achievable in most recirculating systems.

6.3.4 Other Production Systems: Alligators

Water conservation measures at alligator production systems have focused on reusing or recirculating cleaning water. Each alligator holding pen contains a shallow pool that accumulates waste products and must be cleaned regularly to remove the wastes and ensure good skin quality for the alligators. The pen-cleaning process takes place daily or every other day and causes the loss of a large amount of heated water (Delos Reyes, Jr. et al., 1996). Properly operating recirculating systems can reduce daily loss of heated water to as little as 5% (Delos Reyes, Jr. et al., 1996), but these systems are not commonly used in alligator production (Pardue et al., 1994; Shirley, 2002, personal communication).

6.4 Pollutants of Concern

6.4.1 Characterization of Pollutants of Concern

Four sources of data were reviewed to provide an initial assessment of the pollutants of concern (1) data from a sampling event at a flow-through facility; (2) data from a sampling event at a recirculating facility; (3) discharge monitoring report (DMR) data submitted to EPA from the EPA regions; and (4) Permit Compliance System (PCS) data from an EPA database.

EPA used several criteria to identify the list of pollutants of concern. For the sampling data, the identification criteria were as follows: (1) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 5 times the minimum limit (ML); (2) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 10 times the ML; and (3) treated effluents with analytes that had at least one reported value with an average concentration greater than 5 times the ML. The results for determining pollutants of concern are presented in Appendix C.

The first two criteria were applied to the same data (e.g., a raw wastewater from a sampling event) and were used as a measure to determine how a more stringent criterion (> 5 ML) contrasted with a less stringent criterion (> 10 ML) in determining an analyte as a pollutant of concern. In almost all cases, both criteria (> 5 ML and > 10 ML) produced the same results.

For the PCS and DMR data sets, the original data were first associated with a system type as defined by NPDES permit information. Parameters with measurements in the DMR and PCS data without a value or with a value of zero were excluded from the data sets and assumed to be nondetectable. All other data were summarized by system type and analyte, with an analysis for the average sampling value, the maximum sampling value, the minimum sampling value, and the number of samples taken.

The PCS and DMR data, composed mainly of state and federal facilities and large commercial facilities that have NPDES permits, represent the best available information. One limitation of the data is the lack of information on pond systems. Generally, the pollutants identified in the DMR or PCS database are included in the list of pollutants of concern (POCs) provided below.

The POCs that are currently indicated for the CAAP industry, based on the available data, include the following: conventional and nonconventional pollutants (ammonia, biochemical oxygen demand, chemical oxygen demand, chlorine, nitrate, nitrite, oil and grease, ortho-phosphate, pH, settleable solids, total Kjeldahl nitrogen, total phosphorus, and total suspended solids), metals (aluminum, barium, boron, copper, iron, manganese, selenium, and zinc), microbiologicals (*Aeromonas*, fecal *streptococcus*, and total coliforms), organic chemicals, and hexanoic acid.

6.4.2 Methodology for Proposed Selection of Regulated Pollutants

EPA selects the pollutants for regulation based on the POCs identified for each subcategory. Generally, a pollutant or pollutant parameter is considered a POC if it was detected in the untreated process wastewater at five times the minimum level in more than 10% of samples. The ML is a metric of the sensitivity of the analytic testing procedure to measure for a pollutant or pollutant parameter.

Monitoring for all POCs is not necessary to ensure that AAP wastewater pollution is adequately controlled because many of the pollutants originate from similar sources (the feed), are associated with the solids, and are treated with the same pollutant removal technologies and similar mechanisms. Therefore, monitoring for one pollutant as a surrogate or indicator of several others might be sufficient.

Regulated pollutants are pollutants for which EPA may establish numerical effluent limitations and standards. EPA evaluates a POC for regulation in a subcategory using the following criteria:

- Not considered a volatile compound.
- Effectively treated by the selected treatment technology option.
- Detected in the untreated wastewater at treatable levels in a significant number of samples, e.g., generally five times the minimum level in more than 10% of the raw wastewater samples.

6.5 POLLUTANTS AND POLLUTANT LOADINGS

CAAP facility effluents can have high concentrations of nutrients and suspended solids, high BOD and low levels of DO. When discharged into receiving waters, effluents with high levels of suspended solids can cause turbidity, which can reduce light available for photosynthesis. Low dissolved oxygen levels can affect estuarine organisms in the receiving waters, and excessive nutrients can accelerate plankton growth, resulting in die-offs and increased BOD in receiving waters.

6.5.1 Sediments and Solids

Solids are the largest pollutant loading generated in CAAP facilities. Most pond systems, however, are managed to capture and hold solids in the pond, where the solids naturally degrade. In addition, management of flow-through and recirculating systems captures most of the generated solids, which must then be properly disposed of. Although most solids are land-applied, solids that leave the facility in the effluent stream can have a detrimental effect on the environment. Many CAAP facilities with NPDES permits must control and monitor their discharge levels of solids. In Idaho, NPDES permits specify average monthly and maximum daily TSS limits that vary according to production and system treatment technology (USEPA, 2002b).

Although some solids from CAAP facilities are land-applied, other solids leave the facility in the effluent stream and can have a detrimental effect on the environment. Suspended solids can degrade aquatic ecosystems by increasing turbidity and reducing the depth to which sunlight can penetrate, which decreases photosynthetic activity and oxygen production by plants and phytoplankton. If sunlight is completely blocked from bottom-dwelling plants, the plants stop producing oxygen and die. As the plants are decomposed, bacteria use up more of the oxygen and decrease dissolved oxygen levels further. Subsequently, low dissolved oxygen can cause fish kills. Decreased growth of aquatic plants also affects a variety of aquatic life, which use the plants as habitat. Increased suspended solids can also increase the temperature of surface water because the particles absorb heat from the sunlight. Higher temperatures result in lower levels of dissolved oxygen because warm water holds less dissolved oxygen than cold water (Murphy, 2000c).

Suspended particles can abrade and damage fish gills, increasing the risk of infection and disease. They can also cause a shift toward more sediment-tolerant species, reduce filtering efficiency for zooplankton in lakes and estuaries, carry nutrients and metals, adversely affect aquatic insects that are at the base of the food chain (Schueler and Holland, 2000), and reduce fish growth rates (Murphy, 2000c). Suspended particles reduce visibility for sight feeders and disrupt migration by interfering with a fish's ability to navigate using chemical signals (USEPA, 2000). Finally, suspended particles cause a loss of sensitive or threatened fish species when turbidity exceeds 25 nephelometric turbidity units (NTU) and a decline in sunfish, bass, chub, and catfish when monthly turbidity exceeds 100 NTU (Schueler and Holland, 2000).

As sediment settles, it can smother fish eggs and bottom-dwelling organisms, interrupt the reproduction of aquatic species, destroy habitat for benthic organisms (USEPA, 2000) and fish spawning areas, and contribute to the decline of freshwater mussels and sensitive or threatened darters and dace. Deposited sediments also increase sediment oxygen demand, which can deplete dissolved oxygen in lakes or streams (Schueler and Holland, 2000).

Increased levels of suspended solids and nutrients have very different effects on aquatic plants. High levels of suspended solids can kill off desirable species, while elevated nutrient levels can cause too many plants to grow. In either situation, an ecosystem can be drastically altered by increases in these pollutants. As a result, it is important to maintain a balance in the levels of suspended solids and nutrients reaching waterbodies to reduce such drastic impacts on aquatic plants.

6.5.2 Nutrients

Nitrogen from CAAP facilities is discharged mainly in the form of nitrate, ammonia, and organic nitrogen. Most nitrogen from these facilities, however, is in the form of ammonia, which is not usually found at toxic levels in CAAP discharges. Some facilities with ponds and recirculating systems might also have high levels of nitrite. Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This decomposition consumes oxygen, reducing dissolved oxygen levels and adversely affecting aquatic life. Phosphorus is discharged from CAAP facilities in both the solid and dissolved forms. The dissolved form, however, poses the most immediate risk because it is available to plants. Although the solid form of phosphorus is generally unavailable, depending on the environmental conditions, some phosphorus may be slowly released from the solid form.

6.5.2.1 Nitrogen

Nitrates cause problems in aquatic environments because they are directly available for plant or algae uptake (Murphy, 2000a). They are soluble in water and do not bind to particles, making them highly mobile (Kaufman and Franz, 1993). Elevated levels of nitrate cause increased plant and algae growth. When the algae sink to the bottom and die, they are decomposed by bacteria, which consume oxygen. As a result, increased nitrate indirectly decreases dissolved oxygen, and low dissolved oxygen can adversely affect fish and other aquatic life. This process is referred to as eutrophication. In addition, high concentrations of nitrate and/or nitrite can produce “brown blood disease” in fish. In this disease, the blood is unable to carry enough oxygen, despite adequate oxygen in the surrounding water (Murphy, 2000a). As a result, fish may die of suffocation.

Ammonia causes two main problems in the aquatic environment. First, it can be toxic to aquatic life, affecting hatching and growth rates of fish. For example, when un-ionized levels of ammonia exceed 0.0125 to 0.025 mg/L, growth rates of rainbow trout are reduced and damage to liver, kidney, and gill tissue may occur (Murphy, 2000a). Second, ammonia is easily converted to nitrate in waters where oxygen is available. Once ammonia is converted to nitrate, it is available for plant uptake. As previously mentioned, elevated levels of nitrate may increase plant and algae growth, which can decrease dissolved oxygen levels and affect aquatic life (Murphy, 2000a). The proportion of total ammonia in the un-ionized form can vary with temperature and pH levels (IDEQ, n.d.). Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This process consumes oxygen, reducing dissolved oxygen levels and adversely affecting aquatic life.

6.5.2.2 Phosphorus

CAAP facilities release phosphorus in both the solid and dissolved forms. Although the solid form is generally unavailable, the dissolved form is readily available and it poses the most immediate risk to the environment. Plants and bacteria require phosphorus in the dissolved form, generally as orthophosphate, for their nutrition (Henry and Heinke, 1996). Phosphates are not toxic unless they are present at very high levels (Murphy, 2000b); however, excessive amounts of orthophosphate in the aquatic environment increase algae and aquatic plant growth. As before, this change results in decreased dissolved oxygen levels as bacteria decompose dead algae, consuming oxygen in the process. When dissolved oxygen concentrations fall below the levels required for metabolic requirements of aquatic biota, both lethal (e.g., fish kills) and sublethal effects can occur. Oxygen loss in bottom waters can also free phosphorus previously trapped in the sediment, increasing the amount of available phosphorus and continuing the process of decreasing dissolved oxygen (Murphy, 2000b).

Nitrogen and phosphorus are the primary causes of cultural eutrophication. The most recognizable evidence of eutrophication is algal blooms that occur during the summer. Symptoms of nutrient overenrichment include murky water, low dissolved oxygen, fish kills, and depletion of desirable flora and fauna. In addition, the increase in algae and turbidity in drinking water supplies heightens the need to chlorinate drinking water. Chlorination, in turn, leads to higher levels of disinfection by-products that have been shown to increase the risk of cancer. Excessive amounts of nutrients can also stimulate the activity of microbes, such as *Pfiesteria piscicida* that may be harmful to human health (Grubbs, 2001).

6.5.3 Organic Compounds and Biochemical Oxygen Demand

Organic matter is discharged from CAAP facilities primarily from feces and uneaten feed. Elevated levels of organic compounds contribute to eutrophication and oxygen depletion. This occurs because oxygen is consumed when microorganisms decompose organic matter. BOD is used to measure the amount of oxygen consumed by microorganisms when they decompose the organic matter in a waterbody. The greater the BOD, the greater the degree of pollution and the less oxygen available. When a sufficient level of oxygen is not available, aquatic species become stressed and might not eat well. Their susceptibility to diseases can increase dramatically, and some species might even die. Even small reductions in dissolved oxygen can lead to reduced growth rates for sensitive species.

6.5.4 Metals

Metals may be present in CAAP wastewaters for various reasons. They might be used as feed additives, occur in sanitation products, or result from deterioration of CAAP machinery and equipment. Many metals are toxic to algae, aquatic invertebrates, or fish. Although metals can serve useful purposes in CAAP operations, most metals retain their toxicity once they are discharged into receiving waters. EPA observed that many of the treatment systems used in the CAAP industry provide substantial reductions of most metals. Because most of the metals are present in particulate form or bind to solid particles, they can be adequately controlled by controlling solids.

6.6 SPECIAL POLLUTANTS

6.6.1 Pathogens

Pathogens associated with the CAAP industry include those that can impair human health and those that are harmful to aquatic animals if discharged. Total coliform bacteria, fecal coliform bacteria, *Esherichia coli*, fecal streptococci, *Enterococcus faecium*, *Mycobacterium marinum*, and *Aeromonas* were sampled at two of the sampling event facilities to determine the presence of these indicator organisms in CAAP effluents. Sampling points included influent water, process water, treated effluents, and solids storage effluents. Most of the data show nondetectable levels of these organisms, including in influent water. However, some of the indicators, including *aeromonas*, total coliform bacteria, and fecal *streptococcus*, had average measured levels greater than 60,000 bacteria/100 mL in treated effluents and solids storage effluents.

6.6.1.1 Human Health Concerns

When testing for the presence of pathogens, it is important to note that there is a distinction between indicator microorganisms and pathogens. Human pathogens found in aquatic systems can include bacteria (e.g., *Salmonella* sp., *Vibrio* sp.), viruses (e.g., Norwalk viruses, enteroviruses, rotaviruses), and protozoans (e.g., *Cryptosporidium parvum*, *Giardia intestinalis*). EPA has long recognized that it is difficult to assay waters for the presence of human pathogens. Given the difficulty in detecting pathogens in aquatic systems, EPA relies on the detection of indicator microorganisms, which are used to infer the presence of pathogens and to predict public health risks due to ingestion or contact with water.

A range of indicator organisms has been used over time. However, all indicator organisms have a few common traits: (1) they are commonly found in contamination that also contains pathogens, (2) they persist in the aquatic environment as long as pathogens, and (3) they can be easily detected. Total coliforms, fecal coliforms (or more specifically *E. coli*), and enterococci have all been used as indicators of water quality. Even though these bacterial indicators have been used with some success for protecting public health, they are limited in their use in more complex systems. Because of varying rates of degradation and persistence in aquatic environments, these bacterial indicators do not always adequately represent risk due the presence of pathogenic bacteria.

Human pathogens in CAAP effluents can stem from animal feed, other animals, and source waters to the facility. In the majority of cases, levels of human pathogens are likely to be minimal, especially in finfish CAAP facilities. Transfer of animal viral pathogens to humans is highly unlikely because most viruses are species-specific.

CAAP facilities are not considered a significant source of pathogens that adversely affect human health (MacMillan et al., 2002). CAAP facilities culture cold-blooded animals (fish, crustaceans, molluscs, etc.) that are unlikely to harbor or foster pathogens that would adversely affect warm-blooded animals like humans by causing disease. CAAP facilities could become contaminated with such pathogens if, for example, wastes from warm-blooded animals were to contaminate CAAP facility waters or the source waters used by CAAP facilities, but this is not considered a substantial risk in the United States (MacMillan et al., 2002).

6.6.1.2 Aquatic Animal Pathogens

Most fish pathogens are not hazardous to humans; however, some, such as streptococcus bacteria, can infect humans. Transfer of other microorganisms like *Vibrio* sp. and protozoan pathogens could also be expected. High levels of antibiotics and genetically engineered components in fish feed (e.g., soya additives) can also pose risks due to increased antibiotic resistance. At this point, the amount of research conducted in this area is so small that no concluding statements can be made regarding the need to regulate effluents based on their pathogen content.

Fish pathogens already exist in the natural environment. Theories of disease must account for the fact that in any community, a large percentage of healthy normal individuals continually harbor potentially pathogenic microbes without suffering any symptoms (Dubos, 1955). In aquaculture, fish are no longer in the natural environment; instead, they are confined within a finite amount of space from which they cannot escape even when conditions become undesirable or unbearable. It is the responsibility of the fish culturist to prevent such conditions from occurring because of increased susceptibility of fish to diseases when raised in artificial environments. Not only do disease outbreaks cause economic hardship, but the affected facility also becomes a primary site to amplify the specific disease organism, potentially disseminating these pathogens into the natural environment.

Obligate fish pathogens are pathogens that cannot survive as free-living organisms but depend on a fish host for their continuous survival and propagation. These pathogens include viruses, bacteria, and protozoans such as *Myxosoma cerebralis,* which causes whirling disease*; Ceratomyxa shasta,* which infects salmonids; viral hemorrhagic septicemia (VHS); and *Yersinia ruckeri,* which causes enteric redmouth (ERM). Facultative pathogens, such as Motil Aeromonas Septicemia (MAS) caused by *Aeromonas hydrophila,* can live independently of a host organism by obtaining nutrients from organic matter present in the environment. These opportunistic bacteria are ubiquitous on a worldwide scale in freshwater environments and typically can cause disease episodes after fish have been exposed to unfavorable temperatures, low dissolved oxygen levels, accumulated metabolic waste products, handling, marking, and crowding (Meyer, 1970). There are two major strategies to avoid outbreaks of fish diseases in aquaculture facilities: (1) keep obligate fish pathogens out and (2) avoid stress by maintaining proper water quality conditions.

CAAP facilities can be sources of infectious disease transmission to wild populations of aquatic organisms. Such infectious diseases include those caused by pathogens that are exotic to native ecosystems, as well as the much larger group caused by pathogenic microbes that already exist in wild fish populations. For example, wastes and escapement of infected shrimp from CAAP facilities is considered a major potential pathway for wild shrimp exposure to viral diseases (JSA Shrimp Virus Work Group, 1997). In addition, in light of potentially serious risks of disease transmission from hatcheries to wild populations, guidelines (USDA, 2002) have been developed to define certain practices to prevent the spread of pathogens that might result from the release of infected salmon from hatcheries.

There are a number of studies that indicate how CAAP facilities may be sources of disease transmission to wild populations. For example, the Asian tapeworm *Bothriocephaus acheilognathi* was identified in North America in 1975 in fish farms where golden shiners *Notemigonus crysoleucas*, fathead minnows *Pimephales promelas*, and grass carp were raised. More recently, the use of poeciliids, such as mosquitofish *Gambusia affinis*, for mosquito control and possible releases of exotic fishes from aquaria have been suggested as mechanisms for introduction of the parasite into native fish in areas such as Hawaii. Font and Tate (1994) found that native Hawaiian fish from streams where no exotic species were found were completely free of adult helminthes (a type of parasite). Conversely, in two rivers with exotic species, nematodes and Asian tapeworms were found in both the exotic species and the native fish (Blazer and LaPatra, 2002).

Another parasite associated with fish farms is *Myxobolus cerebralis*, which causes whirling disease. The disease was first identified in the United States in 1956 in brook trout in Pennsylvania. Although widely distributed by the 1970s, clinical whirling disease was only reported in fish from CAAP facilities. However, a survey of wild fish in Michigan found that the parasite had become established in native brook and brown trout below a CAAP facility that contained infected fish. Other surveys have observed a lack of effect on wild populations. The fact that *M. cerebralis* may cause effects in some wild populations and not others makes whirling disease the subject of much current research (Blazer and LaPatra, 2002).

Blazer and LaPatra's (2002) discussion on the potential pathogen risks to wild fish populations from cultured fish also provided a summary of risks from viruses, such as infectious hematopietic necrosis virus (IHNV), infectious pancreatic necrosis virus (IPNV), and infectious salmon anemia virus (ISAV), and bacteria, such as *Edwardsiella ictaluri* and *Renibacterium salmoninarum*. Although these viruses and bacteria are hazardous to wild fish populations, a weaker causative association was made between CAAP facilities and disease outbreaks in wild populations.

6.6.2 Nonnative Species

Some aquatic animal species in commercial production are considered "nonnative" to the geographic area of production. These are species that have been brought into the United States from abroad or into a region of the United States where they would not occur naturally. Whenever nonnative species are introduced to an area, there is potential for these species to become invasive, outcompeting and threatening the survival of the native species. There is also the potential that the introduction of nonnative species may introduce diseases against which native populations have no natural defenses. The Department of the Interior's Fish and Wildlife Service, along with the Department of Commerce's National Marine Fisheries Service, oversee the introduction of nonnative species into the United States.

In addition, many state Departments of Fish and Wildlife have established programs to control the introduction and release of nonnative species within their states. The United States, however, has banned the importation of very few nonnative species. There are several examples of species becoming established in the United States (e.g., Atlantic salmon, grass carp, and some ornamental species) after being introduced, in part, through aquatic animal production. Potential problems associated with the introduction and establishment of nonnative species include disease, parasitism, interbreeding with native species, habitat destruction, and competition with native species.

The introductions of nonnative aquatic organisms, through intentional or accidental releases from CAAP facilities, can cause adverse environmental impacts. There is great inconsistency in the terminology used by literature and scientists when discussing nonnative species. Therefore, it is important to note that a nonnative species is defined as an individual, group, or population of a species that is introduced into an area or ecosystem outside its historical or native geographic range. One glossary in which the term *nonnative* is defined considers the term to include both foreign (exotic) and transplanted species and uses it synonymously with "alien" and "introduced" (Fuller et al., 1999).

6.6.2.1 General Impacts

Nonnative species, which are often considered biological pollutants, can alter and degrade habitat. When species are introduced into new habitats, they often overrun the area and crowd out new species. If enough food is available, populations of nonnative species can increase considerably. Once they are established in an area, they can be difficult to eliminate (UMN, 2000).

Many nonnative species are introduced into the environment by accident when they are carried into an area by vehicles, ships, produce, commercial goods, animals, or clothing

(UMN, 2000) or when they escape from CAAP facilities. Other species are introduced intentionally. Although some species can be harmless or beneficial to an environment, others can be detrimental to ecosystems and recreation (UMN, 2000).

Impacts of nonnative aquatic organisms on native aquatic species in North America can be classified into five general categories: habitat alteration, trophic alteration, spatial alteration, gene pool deterioration, and introduction of diseases.

6.6.2.2 Habitat Alteration

Nonnative fish, such as carp and tilapia, introduced to control vegetation can cause a variety of habitat impacts. Both exotic and native vegetation can be destroyed as a result of carp predation. This, in turn, results in bank erosion, restrictions on fish nursery areas, and acceleration of eutrophication as nutrients are released from the plants. Grass carp can adversely affect rice fields and waterfowl habitat, while common carp reduce vegetation by direct consumption and by uprooting, as they dig through the substrate in search of food. Digging also increases turbidity in the water (AFS, 1997; Kohler and Courtenay, n.d.).

6.6.2.3 Trophic Alteration

Nonnative species can also cause complex and unpredictable changes in community trophic structure. Communities can be changed by explosive population increases of nonnative fish or by predation of native species by introduced species (AFS, 1997). Several studies have documented dietary overlap in native and introduced fishes. As a result, there is potential for competition. However, it has proven difficult to link dietary overlap to competition (Kohler and Courtenay, n.d.).

6.6.2.4 Spatial Alteration

Spatial changes can result from overlap in the use of space by native and nonnative fish, which can lead to competition if space is limited or of variable quality (AFS, 1997).

6.6.2.5 Gene Pool Deterioration

Heterogeneity can be decreased through inbreeding by species being produced in a hatchery. This risk is most serious with species of intercontinental origin because the initial broodstock already has a limited gene pool. If these species are introduced to new habitat, they might lack the genetic characteristics necessary for them to adapt or perform as predicted. There is also a possibility that native gene pools might be altered through hybridization when nonnative species are introduced to a habitat; however, hybridization events in open waters are rare (AFS, 1997; Kohler and Courtenay, n.d.).

6.6.2.6 Introduction of Diseases

Nonnative species can transmit diseases caused by parasites, bacteria, and viruses to an environment. The transmission of diseases from nonnative species to native species is considered one of the most serious threats to native communities (AFS, 1997).

There are numerous examples of nonnative species introducing diseases in native species. Transfer of diseased nonnative fish from Europe is believed to be responsible for introducing whirling disease in North America. Infectious hypodermal and hematopoietic necrosis (IHHN) virus has been spread to a number of countries as a result of shipments of live penaeid shrimp. IHHN was first diagnosed at Hawaiian shrimp culture facilities in shrimp from Panama. "Ich," a common fish disease that is caused by a ciliated protozoan, might have been transferred from Asia throughout the temperate zone with fish shipments (Kohler and Courtenay, n.d.).

6.6.3 Nonnative Species Associated with CAAP Facilities

Potentially nonnative species associated with CAAP facilities include Atlantic salmon, grass carp, shrimp, and tilapia.

6.6.3.1 Atlantic Salmon

Atlantic salmon (*Salmo salar*) are raised in net pens off the east and west coasts of the United States and in British Columbia. Escapement has become a concern to some, particularly Alaska, because of potential impacts from disease, parasitism, interbreeding, and competition. In areas where the salmon are exotic (i.e., the West Coast), most concerns focus not on interbreeding with other salmon species but on whether the escaped salmon will establish feral populations, reduce the reproductive success of native species through competition, alter the ecosystem in some unpredictable way, or transfer diseases (EAO, 1997).

Although it remains uncertain whether escaped farmed Atlantic salmon can definitely transfer diseases, it is useful to examine some biological information on escaped salmon reported by the Environmental Assessment Office of British Columbia. Between 1991 and 1995, 90 adult Atlantic salmon recovered in British Columbia and Alaska were examined to determine if they were infected with any diseases. Two fish were infected with *Aeromonas salmonicida*, the causative agent of furunculosis, and none of the fish contained unusual parasite infestations. Additionally, none of the 56 fish tested were infected with common viral infections (Alverson and Ruggerone, 1998).

In contrast, Atlantic salmon stocked in Puget Sound were believed to have been responsible for introducing a new disease, viral hemorraghic septicemia (VHS), to the west coast. This disease has been found in two salmon hatcheries in Puget Sound (Dentler, 1993). VHS is a systemic infection of various salmonid and a few nonsalmonid fish. It is caused by a rhabdovirus and can cause significant cumulative mortality. Fish that survive become carriers of the disease. VHS is constantly present in most countries of continental Eastern and Western Europe. However, the virus has been isolated off the coast of Washington, in Puget Sound (McAllister, 1990).

Experiments have shown that Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*), golden trout (*Oncorhynchus aguabonita*), rainbow trout x coho salmon hybrids, giebel (*Carassius auratus gibelio*), sea bass (*Dicentrarchus labrax*), and turbot (*Scophthalmus maximus*) are all susceptible to VHS. Experiments have also shown that common carp (*Cyprinus carpio*), chub (*Leuciscus cephalus*), Eurasian perch (*Perca fluviatilis*), roach (*L. rutilus*), and tench (*Tinca tinca*) are all resistant to VHS (McAllister, 1990).

6.6.3.2 Grass Carp

The grass carp (*Ctenopharyngodon idella*), or white amur, is native to the Amur River in China and Russia. It was first imported to the United States in 1963 by aquaculture facilities in Alabama and Arkansas and is used for biological control of vegetation. In the past few decades, the grass carp has spread rapidly as a result of research projects; escapes from ponds and aquaculture facilities; legal and illegal interstate transport; releases by individuals and groups; stockings by federal, state, and local government agencies; and natural dispersion from introduction sites (Dill and Cordone, 1997; Lee et al., 1980; Pflieger, 1975).

Many states have restrictions on the use of grass carp. For example, Pennsylvania, New Jersey, Delaware, and Virginia have all approved the use of grass carp for weed control, with certain restrictions. These states require that the fish be "triploid," meaning that they must have three sets of chromosomes instead of two, which makes the fish sterile (University of Delaware, 1995). Although researchers have reported that the probability of successful reproduction of triploid grass carp is "virtually nonexistent" (Loch and Bonar, 1999), some researchers have questioned the sterility of triploids because techniques used to induce triploidy are not always effective. Therefore, each fish should be genetically checked (USGS, 2001). In addition, measures should be taken to reduce the number of escapes by these fish. Barriers could be constructed and maintained to prevent migration from lakes. Consideration should also be given to the location and type of water bodies stocked with grass carp. Lakes and ponds that are prone to flooding should not be stocked with these carp (Loch and Bonar, 1999).

According to the literature, there are a variety of actual and potential impacts of introducing grass carp to an area. Shireman and Smith (1983) concluded that the effects of grass carp on a water body are complex and depend on the stocking rate, the macrophyte abundance, and the ecosystem's community structure. Negative effects of grass carp include interspecific competition for food with invertebrates and other fish, interference with fish reproduction, and significant changes in the composition of macrophyte, phytoplankton, and invertebrate communities. Chilton and Muoneke (1992) reported that grass carp might affect other species indirectly, by modifying preferred habitat, or directly, through predation or competition when food is scarce. Bain (1993) reports that grass carp have significantly altered the food web and trophic structure of aquatic ecosystems by causing changes in fish, plant, and invertebrate communities. More specifically, he indicates that these effects are largely a result of decreased density and composition of aquatic plants.

The removal of vegetation by grass carp can result in the elimination of food, shelter, and spawning substrates for native fish (Taylor et al., 1984). Additionally, the partial digestion of plant material by grass carp results in increased phytoplankton populations because grass carp can digest only half of the plant material they consume. The rest of the material is released into the water and increases algal blooms (Rose, 1972), which decreases oxygen levels and reduces water clarity (Bain, 1993).

Grass carp may carry diseases and parasites that are known to be infectious or potentially infectious to native fish. Grass carp imported from China are believed to be responsible for introducing the Asian tapeworm *Bothriocephalus opsarichthydis* (Ganzhorn et al., 1992; Hoffman and Schubert, 1984).

6.6.3.3 Pacific White Shrimp

The Pacific white shrimp (*Paneaus vannamei*) and the blue shrimp *(P. stylirostris*) from the Pacific coast of Central and South America were introduced to the United States as productive culture species for the U.S. industry, when smaller native species (brown shrimp (*P. aztecus*), white shrimp (*P. setiferus*), and pink shrimp (*P. duorarum*) proved unsuitable for commercial production. The giant tiger prawn (*P. monodon*) from the western Pacific has also been introduced into the United States for shrimp farming.

Today most commercial ventures in the United States produce the Pacific white shrimp for a single annual crop (Iverson et al., 1993). Most shrimp farms are in South Carolina, Florida, and Texas. Escapement of nonnative shrimp is a major concern because of the possible spread of disease, as well as various bacterial, fungal, and viral infections, to wild populations. Because diseases like white spot disease are very contagious and have high mortality rates, states have taken precautions to prevent escapement from shrimp farms. Other diseases that commonly affect shrimp include infectious hypodermal and hematopoietic necrosis (IHHN) virus, Taura syndrome virus (TSV), and the yellow head virus syndrome (YHV) (Treece, 2000). In Florida state laws regulate where Pacific white shrimp can be grown, including containment within controlled facilities. Texas and South Carolina have similar guidelines to prevent the release of nonnative shrimp and to minimize their potential impact on wild populations. In Texas, the Pacific white shrimp is the only nonnative species permitted to be cultured in AAP facilities.

6.6.3.4 Tilapia

The most commonly raised species of tilapia are blue tilapia (*Oreochromis aureus*), Nile tilapia (*O. niloticus*), and Mozambique tilapia (*O. mossambicus*). Native to Africa and the Middle East, tilapia have been introduced throughout the world as cultured species in temperate regions (Stickney, 2000). They are freshwater fish from the family Cichlidae and are primarily herbivores or omnivores. Feeding lower on the food chain has enhanced their popularity as a culture species (Stickney, 2000). Tilapia were first introduced to the Caribbean islands in the 1940s and then eventually were introduced to Latin America and the United States. In addition to production for foodfish, one species, *Tilapia zillii*, an herbivore, has been stocked in irrigation canals to control aquatic vegetation. Tilapia have also been used for aquarium and bait bucket releases, as a sport fish, and as forage for warmwater predatory fish (Courtenay et al., 1984; Courtenay and Williams, 1992; Lee et al., 1980).

Tilapia are competitors with native species for spawning areas, food, and space (USGS, 2000a). There have been reports that certain streams where blue tilapia are abundant have lost most vegetation and nearly all native fish (USGS, 2000a). In Hawaii, Mozambique tilapia has been considered a significant factor in the decline of the desert pupfish (*Cyprinodon macularius*) in the Stalton Sea area (USGS, 2000b)

Because of its nonnative status, the tilapia has been regulated by various states to prevent escapement and impacts on wild stocks of native species. Importation and movement of tilapia are regulated in the United States. The following states have some form of restriction on tilapia culture: Arizona, California, Colorado, Florida, Hawaii, Illinois, Louisiana, Missouri, Nevada, and Texas (Stickney, 2000).

6.6.4 Drugs and Chemicals

Drugs are substances, including medicated feed, that are added to the production facility to maintain or restore animal health, and they can be subsequently discharged into the waters of the United States. The following summary includes drugs that can be injected directly into aquatic animals or used in immersion baths, but are not discharged to the waters of the United States; however, the proposed rule does not address this category of drugs. Chemicals are substances that are added to an AAP facility to maintain or restore water quality for aquatic animal production and that subsequently might be discharged to waters of the United States.

By providing food and oxygen, AAP facilities can produce fish and other aquatic animals in greater numbers than natural conditions would allow. This means that system management is important to ensure that the animals do not become overly stressed, making them more vulnerable to disease outbreaks. When diseases do occur, facilities might be able to treat their populations with drugs. Operators producing aquatic animals that are being produced for human consumption must comply with requirements established by the Food and Drug Administration (FDA) with respect to the drugs that can be used to treat their animals, the dose that can be used, and the withdrawal period that must be achieved before the animals can be harvested. Drugs can be divided into four categories: approved drugs, investigational drugs, extra-label use drugs, and unapproved drugs. Approved drugs have already been screened by the FDA to ensure that they do not cause significant adverse public health or environmental impacts when used in accordance with label instructions. Currently, there are only six approved drugs for AAP species consumed by humans:

- Chorionic gonadotropin (Chorulon)
- Oxytetracycline (Terramycin)
- Sulfadimethoxine, ormetoprim (Romet-30)
- Tricane methanesulfonate (Finquel and Tricane-S)
- Formalin (Formalin-F, Paracide and Parasite-F)
- Sulfamerazine

FDA authorizes use of investigational drugs on a case-by-case basis to allow a way of gathering data for the approval process (21 USC 3606(j)). Quantities and conditions of use are specified. FDA, however, sometimes relies on the NPDES permitting process to establish limitations on pollutant discharges to prevent environmental harm. NPDES permits to date have required only reporting of the use of drugs and chemicals. EPA suspects that permits have not established limitations on the use of drugs and chemicals because of the frequency of use and the lack of analytical methods to measure such drugs and chemicals in wastewater matrices. Extra-label drug use is restricted to use of approved animal and human drugs by, or on the order of, a licensed veterinarian and must be within the context of a valid veterinarian-patient relationship. New unapproved animal drugs are sometimes used in discrete cases where the FDA exercises its regulatory discretion.

6.6.4.1 FDA-Approved Animal Drugs

Drugs included in this category are those that the FDA has approved for use at AAP facilities. These drugs are widely used at facilities to treat various specified diseases and species, often at application rates that are greater than necessary. Because of the widespread use of some of these drugs, there is potential for antibiotic resistance.

Antibiotics are typically applied orally or by immersion. These routes can allow significant amounts of antibacterial agents (through uneaten medicated feed or leached, unabsorbed, or excreted drug) to escape into the environment and cause resistance. A number of studies support the fact that antibacterial resistance is associated with the frequency of antibiotic use in an environment. Additionally, the frequency of resistance can be increased by antibacterial agent concentrations that are inadequate for killing the bacteria. Insufficient concentrations may result from choosing the wrong drug, failure to deliver the proper dose, faulty treatment regimes, prophylactic treatment, and heavy reliance on a limited number of antibacterial agents because of regulations or specific applicator preferences (GESAMP, 1997).

Table 6.6-1 describes the drugs approved by the FDA for use at AAP facilities, their approved uses, and their environmental effects.

Table 6.6-1. FDA-Approved New Animal Drugs for Aquaculture

Drug	Use	Environmental Effects
Formalin (All finfish eggs)	Control of the fungi of the family of Saprolegniaceae	*Fate in the Environment*: The Center for Veterinary Medicine has found that no environmental impacts are expected from using formalin, provided that the finfish egg treatment water is diluted 100-fold. *Aquatic Life*: A National Fisheries Research Center study showed that formalin concentrations of 1,000 to 2,000 ppm is safe for finfish eggs of the orders Cypriniformes (common carp and white sucker), Perciformes (walleye), and Siluriformes (channel catfish). *Human Health*: An Auburn University study showed that the use of formalin at the recommended concentration (1,000 to 2,000 μL/L for 15 minutes for all finfish eggs except Acipenseriformes and up to 1,500 μL/L for 15 minutes for Acipenseriformes eggs) has not been shown to result in formaldehyde accumulation above naturally occurring levels in the edible tissues of these fish. Source: FDA, n.d.a.
Formalin (All finfish)	Control of the external protozoa and monogenetic trematodes	*Fate in the Environment*: The Center for Veterinary Medicine has determined that no environmental impacts are expected from using formalin, provided that the finfish treatment water is diluted 10-fold. *Aquatic Life*: Tolerances to formalin may vary with strains and species of finfish. Auburn University studies indicated that mortality may occur in striped bass exposed to more than 250 ppm for more than 1.5 hours and that the 96-hour LC_{50} for hybrid striped bass was 60.1 ppm. *Human Health*: An Auburn University study showed that the use of formalin at the recommended concentration (up to 250 μL/L for up to 1 hour in tanks and raceways and 15 to 25 μL/L indefinitely in earthen ponds) has not been shown to result in the accumulation of formaldehyde above naturally occurring levels in the edible tissues of a wide range of cold and warm water fish, including striped bass, the most sensitive species. Source: FDA, n.d.a.

Drug	***Use***	***Environmental Effects***
Human chorionic gonadotropin (HCG) Chorulon is the recommended HCG product for use with brood finfish	Aid in improving spawning function in all male and female brood finfish	*Fate in the Environment*: The Center for Veterinary Medicine has concluded that HCG does not individually or cumulatively have a significant effect on the human environment. *Aquatic Life*: Chorionic gonadotropin should be administered, depending on the fish species, at a dose of 50 to 510 I.U. per pound body weight for males and 67 to 1,816 I.U. per pound body weight for females, for one to three injections. Animal safety studies indicate that HCG can be administered to broodfish at the levels recommended in the product labeling without significant adverse effects. *Human Health*: The total dose administered (all injections combined) must not exceed 25,000 I.U. (25 mL) in fish intended for human consumption. There is no withdrawal period required for broodfish treated according to label directions. For specific dose recommendations and summaries of animal safety and human health studies for various species, refer to FDA, 1999. Source: FDA, 1999
Oxytetracycline (catfish)	Control of bacterial hemorrhagic septicemia and pseudomonas disease	No environmental fate information was available. *Aquatic Life*: The FDA recommends 2.5 to 3.75 g per 100 lb of fish per d, administered in mixed ration for 10 d. Oxytetracycline should not be administered when water is below 16.7 °C (62 °F). *Human Health*: Fish should not be liberated or slaughtered for 21 d following the last administration of medicated feed. Source: FDA, 1996
Oxytetracycline (lobster)	Control of gaffkemia	No environmental fate information was available. *Aquatic Life*: The FDA recommends 1 g/lb, fed for 5 d as the sole ration. *Human Health*: Oxytetracycline should be withdrawn from feed 30 d before harvesting lobsters. Source: FDA, 1996
Oxytetracycline (salmonids)	Control of ulcer disease, furunculosis, bacterial hemorrhagic septicemia, and pseudomonas disease	No environmental fate information was available. *Aquatic Life*: The FDA recommends 2.5 to 3.75 g per 100 lb of fish per d, administered in mixed ration for 10 d. Oxytetracycline should not be administered when water is below 9 °C (48.2 °F). *Human Health*: Fish should not be liberated or slaughtered for 21 d following the last administration of medicated feed. Source: FDA, 1996

Drug	Use	Environmental Effects
Oxytetracycline (pacific salmon)	Marking of skeletal tissue	No environmental fate information was available. *Aquatic Life*: The FDA recommends 250 mg per kilogram of fish per d (11.35 g per 100 lb of fish per d) for salmon not over 30 g body weight, administered as sole ration for 4 d in feed. *Human Health*: Fish should not be liberated for at least 7 d following the last administration of medicated feed. Source: FDA, 1996
Sulfadimethoxine and ormetroprim (catfish)	Control of enteric septicemia	No environmental fate or aquatic life information was available. *Human Health*: Sulfadimethoxine and ormetroprim have a 3-d withdrawal time for catfish. Source: FDA, 2002
Sulfadimethoxine and ormetroprim (salmonids)	Control of furunculosis	No environmental fate or aquatic life information was available. *Human Health*: Sulfadimethoxine and ormetroprim have a 42-d withdrawal time for salmonids. Source: FDA, 2002
Sulfamerazine (not currently available)	Control of furunculosis for rainbow trout, brook trout, and brown trout	No environmental fate or aquatic life information was available. *Human Health*: Sulfamerazine has a 21-d withdrawal time. Source: FDA, 2002
Tricaine methanesulfonate	Temporary immobilization (anesthetic) for Ictaluridae, Salmonidae, Esocidae, and Percidae (In other fish and cold-blooded animals, the drug should be limited to hatchery or laboratory use)	No environmental fate information was available. *Aquatic Life*: FDA has not required any animal safety studies for this drug because it is a generic copy of the brand name drug, whose safety has been established. When tricaine methanesulfonate is used in fish food, water temperature should not exceed 10 °C (50 °F) and use should be restricted to Ictaluridae, Salmonidae, Esocidae, and Percidae. *Human Health*: For human food safety, tricaine methanesulfonate may not be used within 21 d of harvesting fish for food. Source: FDA, n.d.b.

6.6.4.2 Drugs of Low Regulatory Priority

The drugs included in this group have undergone review by the FDA and have been determined to be new animal drugs of low regulatory priority (LRP). The FDA is unlikely to object to the use of any of these drugs if the substances are used for the proper indications, at the prescribed levels, and according to good management practices. In addition, the product should be of an appropriate grade for use in food animals and there should not be an adverse effect on the environment (FDA, 1997).

The FDA does not require labeling for low-priority use for chemicals that are commonly used for non-drug purposes even if the manufacturer or distributor promotes the chemical for the permitted low-priority use. However, a chemical that has significant animal or human drug uses in addition to the low-priority aquaculture use must be labeled for the low-priority uses if the manufacturer or distributor uses promotion or other means to establish the intended low-priority use for the product. Additional labeling requirements are available from the FDA (FDA, 1997).

Table 6.6-2 summarizes the LRP drugs, their intended uses, and their environmental effects. Based on the information provided in the table, LRP drugs are expected to cause minimal adverse effects on aquatic life and the environment.

Table 6.6-2. LRP Drugs

Drug	***Use***	***Environmental Effects***
Acetic acid	Used as a dip concentration of 1,000–2,000 milligrams per liter (mg/L) for 1–10 min as a parasticide for fish	*Fate in the Environment*: When released into water, acetic acid should readily biodegrade and it is expected to have a half-life of between 1 and 10 d (J.T. Baker, 2001). *Aquatic Life*: Acetic acid is expected to be slightly toxic to aquatic life. The LC_{50}/96-h values for fish are between 10 and 100 mg/L (J.T. Baker, 2001). Dilution is expected to eliminate pH risks. *Human Health*: Symptoms of exposure to acetic acid include irritation of the eyes, nose, throat, and lungs, vomiting, diarrhea, circulatory collapse, breathing difficulties, coughing, and chest pains (NTP, 1991a).
Calcium chloride	Used to increase water calcium concentration to ensure proper egg hardening. Dosages used would be those necessary to raise calcium concentration to 10–20 mg/L as calcium carbonate. Also used to increase water hardness up to 150 mg/L to aid in maintenance of osmotic balance in fish by preventing electrolyte loss.	*Fate in the Environment*: Based on available information for calcium chloride anhydrous, this material will not biodegrade or bioaccumulate (J.T. Baker, 1999a). *Aquatic Life*: The LC_{50}/96-h values for fish are over 100 mg/L (J.T. Baker, 1999a). *Human Health*: Calcium chloride can cause irritation if it is inhaled, ingested, or comes in contact with the eyes or skin. Ingestion of large doses can lead to renal damage, dehydration, and hypercalcaemia (Syndel, 2001a).
Calcium oxide	Used as an external protozoacide for fingerling to adult fish at a concentration of 2,000 mg/L for 5 s.	*Aquatic Life*: Calcium oxide is expected to be toxic to aquatic life (J.T. Baker, 1998). Dilution is expected to eliminate pH risks. *Human Health*: Calcium oxide can irritate the eyes, skin, nose, and lungs (New Jersey, 1996).
Carbon dioxide gas	Used for anesthetic purposes in cold, cool, and warm water fish.	No environmental effects are expected.

Drug	***Use***	***Environmental Effects***
Fuller's earth	Used to reduce the adhesiveness of fish eggs to improve fish hatchability.	No environmental fate, aquatic life, or human health information was available.
Garlic (whole)	Used to control helminth and sea lice infestations in marine salmonids at all life stages.	No environmental effects are expected.
Hydrogen peroxide	Used at 250–500 mg/L to control fungi on all species and at all life stages of fish, including eggs.	No aquatic life information was available. *Human Health*: Large doses of hydrogen peroxide can cause gastritis, esophagitis, rupture of the colon, proctitis, and ulcerative colitis (NTP, 1991b). Hydrogen peroxide can irritate the eyes, skin, nose, throat, and lungs. It is considered a mutagen and should be handled with extreme caution. Health effects are unlikely to occur with commercial solutions of hydrogen peroxide used as a skin disinfectant (New Jersey, 1998).
Ice	Used to reduce metabolic rate of fish during transport.	No environmental effects are expected.
Magnesium sulfate (Epsom salts)	Used to treat external monogenetic trematode infestations and external crustacean infestations in fish at all life stages. Used in freshwater species. Fish are immersed in a solution of 30,000 mg/L magnesium sulfate and 7,000 mg/L sodium chloride for 5–10 min.	No environmental effects are expected.
Onion (whole)	Used to treat external crustacean parasites and to deter sea lice from infesting external surface of fish at all life stages.	No environmental effects are expected.
Papain	Used as a 0.2% solution in removing the gelatinous matrix of fish egg masses to improve hatchability and decrease the incidence of disease.	No environmental effects are expected.
Potassium chloride	Used as an aid in osmoregulation to relieve stress and prevent shock. Dosages used would be those necessary to increase chloride ion concentration to 10–2,000 mg/L.	*Aquatic Life*: The highest concentration of chloride to which an aquatic community can be exposed briefly without an unacceptable effect is 860 mg/L. The highest concentration of chloride to which an aquatic community can be exposed indefinitely without an unacceptable effect is 230 mg/L (USEPA, 1999a). *Human Health*: Large doses of potassium chloride usually induce vomiting, so acute intoxication by mouth is rare (NTP, 1991c).

Drug	Use	Environmental Effects
Povidone iodine compounds	Used as a fish egg disinfectant at rates of 50 mg/L for 30 min during water hardening and 100 mg/L solution for 10 min after water hardening.	No environmental fate or aquatic life information was available. *Human Health*: There is no evidence of adverse effects from inhalation, ingestion, skin contact, or eye contact with povidone iodine (Syndel, 2001b).
Sodium bicarbonate (baking soda)	Used at 142–642 mg/L for 5 min as a means of introducing carbon dioxide into the water to anaesthetize fish.	No environmental effects are expected.
Sodium chloride (salt)	Used as a 0.5%–1% solution for an indefinite period as an osmoregulatory aid for the relief of stress and prevention of shock. Used as a 3% solution for 10–30 min as a parasticide.	*Freshwater Aquatic Life*: Certain life stages might be affected by changes in sodium chloride concentrations (Syndel, 2001c). The highest concentration of chloride to which an aquatic community can be exposed briefly without an unacceptable effect is 860 mg/L. The highest concentration of chloride to which an aquatic community can be exposed indefinitely without an unacceptable effect is 230 mg/L (USEPA, 1999a). *Human Health*: There is no evidence of adverse effects from inhalation, ingestion, or skin contact with sodium chloride. However, ingesting very large doses may cause nausea, vomiting, diarrhea, dehydration, and congestion in most internal organs (Syndel, 2001c).
Sodium sulfite	Used as a 15% solution for 5–8 min to treat eggs to improve hatchability.	No aquatic life information was available. *Human Health*: Sodium sulfite is an irritant when it is inhaled, ingested, or comes into contact with the eyes. It is unlikely to irritate skin after brief contact, but may be irritating after prolonged contact (Syndel, 2001d).
Urea and tannic acid	Used to denature the adhesive component of fish eggs at concentrations of 15 g urea and 20 g NaCl per 5 L of water for approximately 6 min, followed by a separate solution of 0.75 g tannic acid per 5 L water for an additional 6 min. These amounts will treat approximately 400,000 eggs.	*Fate in the Environment*: Urea may moderately biodegrade in water and is not expected to evaporate significantly (J.T Baker, 1999b). No environmental fate information for tannic acid was available. *Aquatic Life*: Urea has an experimentally determined bioconcentration factor of less than 100 and is not expected to significantly bioaccumulate (J.T. Baker, 1999b). Dilution is expected to eliminate pH risks from tannic acid. *Human Health*: Exposure to urea may cause eye irritation, headache, nausea, convulsions, and vomiting (NTP, 1991d; CDC, n.d.). Tannic acid can irritate the skin and eyes (ProSciTech, 1998).

6.6.4.3 Investigational New Animal Drugs

Investigational new animal drugs (INADs) are those drugs for which FDA has authorized use on a case-by-case basis to allow a way of gathering data for the approval process (21 USC 3606(j)). Quantities and conditions of use are specified. FDA, however, sometimes relies on the NPDES permitting process to establish limitations on pollutant discharges to prevent environmental harm. Table 6.6-3 provides information about INADs, their uses, and their environmental effects.

Table 6.6-3. Investigational New Animal Drugs for Aquaculture

Drug	*Use*	*Environmental Effects*
AQUI-S	Approved for use as an anesthetic and sedative in New Zealand and Australia. It has been used for harvesting salmon since 1994 and is also widely used in transporting lobster, eels, and other finfish (AQUI-S, 1998).	No environmental fate information was available. *Aquatic Life*: Fish have a fast recovery from AQUI-S, which is effective at low concentrations of 10–20 mg/L. Specific efficacy data and dosage information are available from New Zealand Ltd. (AQUI-S, 1998). *Human Health*: There is no withholding period for AQUI-S, allowing the aquatic animal to be harvested for human consumption (AQUI-S, 1998).
Chloramine-T (Halamid)	Halamid is used in major European trout farming countries to prevent and cure bacterial gill disease. It can be used at all stages of farming for the general disinfection of passage bath tanks, pond surfaces and equipment, water preconditioning, water quality maintenance, and disinfecting eggs and artemia. The United States is researching its use in controlling bacterial gill disease in salmonids (FDA, 1998) and flavobacteriosis in cold, cool, and warm water fishes.	According to the manufacturer, Halamid has a low toxicity, is readily biodegradable, and does not accumulate in the environment. Aquatic toxicity information is available from the manufacturer's web site, but a password is required (Halamid, n.d.).

Drug	***Use***	***Environmental Effects***
Copper sulfate (Triangle Brand Copper Sulfate)	Used to control bacterial diseases, fungal diseases, and external protozoan and metazoan parasites.	*Fate in the Environment*: Copper is adsorbed to organic materials and to clay and mineral surfaces. The degree to which it is adsorbed depends on the acidity or alkalinity of the soil. Copper sulfate is highly soluble in water, making it one of the more mobile metals in soil. However, its leaching potential is low in all but sandy soils because of its binding capacity. Copper sulfate can persist indefinitely, although it will bind to water particulates and sediment (Extoxnet, 1996a). Copper sulfate can aggravate low dissolved oxygen problems in ponds by killing the primary source of oxygen (the algae) and by adding a large biochemical oxygen demand in the form of dead and decomposing algae. Therefore, consideration should be given to dissolved oxygen before treating a pond (Cornell, 1998). *Aquatic Life*: Copper sulfate is highly toxic to fish. It can be poisonous to trout and other fish, especially in soft or acidic waters, even when it is applied at recommended rates. Copper sulfate's toxicity to fish tends to decrease as water hardness increases. Fish eggs are more resistant to the toxic effects of copper sulfate than young fish fry. Copper sulfate is also toxic to aquatic invertebrates such as crabs, shrimp, and oysters (Extoxnet, 1996a). *Human Health*: The acute toxicity of copper sulfate is due largely to its being caustic. The lowest dose of copper sulfate that has been toxic when ingested by humans is 11 mg/kg. Ingestion of copper sulfate is often not toxic because vomiting is an automatic reflex of its irritation of the gastrointestinal tract. However, symptoms are severe if it is retained in the stomach. Symptoms include a burning pain in the chest and abdomen, intense nausea, repeated vomiting, diarrhea, headache, sweating, shock, and injury to the brain, liver, kidneys, and stomach (Extoxnet, 1996a). It can also irritate the skin and eyes (Syndel, 2001e). Copper sulfate has been shown to cause reproductive effects in test animals (Extoxnet, 1996a).
Crude carp pituitary	Aid in improving spawning function in various fish (FDA, 1998).	No environmental fate, aquatic life, or human health information was available.
Erythromycin	Control of bacterial kidney disease in salmonids (FDA, 1998).	No environmental fate, aquatic life, or human health information was available.
Florfenicol (Aquflor)	Used to control flexibacteriosis and furunculosis.	No environmental fate, aquatic life, or human health information was available.
Formalin	Used as a fungicide on fish and their eggs at public aquaculture facilities.	Effects vary, based on the concentration used and the conditions in which it is used.

Drug	Use	Environmental Effects
Gonadotropin releasing hormone analog (Ovaplant, Ovaprim)	Ovaplant is used to advance maturation and ovulation and has been tested in Atlantic salmon and other fish species (Syndel, 2001h). Ovaprim is used to promote and facilitate reproduction of many species of fish (Syndel, 2001i).	No environmental fate or aquatic life information was available. *Human Health*: Ovaplant and Ovaprim might be harmful if they are inhaled, ingested, or come into contact with the eyes or skin. Although the toxicological properties have not been studied, it is possible that Ovaplant and Ovaprim might modify reproductive ability (Syndel, 2001f, 2001g).
Hydrogen peroxide	Used to control bacterial gill disease in various fish (FDA, 1998), fungal infections, external bacterial infections, and external parasites.	No environmental fate or aquatic life information was available. *Human Health*: Large doses of hydrogen peroxide can cause gastritis, esophagitis, rupture of the colon, proctitis, and ulcerative colitis (NTP, 1991b). Hydrogen peroxide can irritate the eyes, skin, nose, throat, and lungs. It is considered a mutagen and should be handled with extreme caution. Health effects are unlikely to occur with commercial solutions of hydrogen peroxide used as a skin disinfectant (New Jersey, 1998).
17∝ methyltestosterone	Used in rainbow trout (FDA, n.d.c.).	No environmental fate, aquatic life, or human health information was available.
Oxytetracycline	For control of columnaris in walleye, vibriosis in summer flounder, Streptococcus infection in tilapia (FDA, 1998), and flavobacteriosis in cold, cool, and warm water fishes. Also used in otolith marking of fish.	Effects will vary, based on the concentration used and the conditions in which it is used.
Potassium permanganate (Cairox)	Used to control external Ichthyophthirius multifilis in catfish (FDA, 1997), external protozoan, metazoan parasites, and bacterial and fungal diseases.	No environmental fate or aquatic life information was available. *Human Health*: Potassium permanganate is an irritant when it is inhaled, ingested, or comes into contact with the eyes, skin, or nasal and respiratory passages. Early symptoms of exposure include sluggishness, sleepiness, and weakness in the legs. Symptoms of advanced cases include fixed facial expression, emotional disturbances, and falling (Syndel, 2001j).

6.6.4.4 Registered Pesticides

Pesticides may be used to control animal parasites and aquatic plants and might be present in wastewaters. Some pesticides are bioaccumulative and retain their toxicity once they are discharged into receiving waters. Although EPA observed that many of the treatment systems used in the CAAP industry provide adequate reductions of pesticides, most systems are not specifically designed and operated to remove pesticides.

Table 6.6-4 provides information about registered pesticides, their uses, and their environmental effects.

Table 6.6-4. Pesticides Registered for Aquaculture

Chemical	***Use***	***Environmental Effects***
Chelated copper	Used to control algae.	Effects are the same as effects of copper.
Copper	Used to control algae.	*Fate in the Environment*: Soluble copper compounds, which dissolve in water, are more likely to threaten human health than those that bind to solids. Soluble copper compounds released into rivers and lakes, however, tend to rapidly become attached to particles in neutral and basic water within almost a day, making these compounds less threatening to human health (ATSDR, 1990). In contrast, copper compounds can leach from acidic environments and as a result become bioavailable and threatening to human health. *Aquatic Life*: Crayfish have an LC_{50} value of 600 micrograms per liter (μg/L) for copper. LC_{50} values for bluegill sunfish have been measured as low as 400 μg/L in soft water. Blue mussel embryos are very sensitive to copper exposure, with an LC_{50} value of 5.8 μg/L for copper sulfate. Generally, juvenile aquatic organisms appear to be more sensitive to the effects of copper compounds than adults (USEPA, 1985). Red blood cell damage in Mozambique tilapia was observed during both 96-h and 4-wk exposure periods to 0.40 mg/L of copper (Nussey et al., 1995). Fathead minnow embryos exhibited a 96-h LC_{50} value of 250 μg/L (Scudder et al., 1988). *Human Health*: At high doses, copper has been shown to cause kidney and liver damage, stomach and intestinal distress, and anemia (TEC, 1998). Symptoms observed from accidental ingestion or intentional poisonings include metallic taste in the mouth, abdominal pain, diarrhea, and vomiting. Ingesting copper in gram amounts can cause systemic toxicity, including liver and kidney damage, intestinal bleeding, cardiovascular effects, convulsions, coma, and death (Faust, 1992).
Copper as elemental	Used to control algae.	Effects are the same as effects of copper.

Chemical	***Use***	***Environmental Effects***
Copper sulfate pentahydrate	Used to control algae.	*Fate in the Environment*: Copper is adsorbed to organic materials and to clay and mineral surfaces. The degree to which it is adsorbed depends on the acidity or alkalinity of the soil. Copper sulfate is highly soluble in water, making it one of the more mobile metals in soil. However, its leaching potential is low in all but sandy soils because of its binding capacity. Copper sulfate can persist indefinitely, although it will bind to water particulates and sediment (Extoxnet, 1996a). Copper sulfate can aggravate low dissolved oxygen problems in ponds by killing the primary source of oxygen (the algae) and by adding a large biological oxygen demand in the form of dead and decomposing algae. Therefore, consideration should be given to dissolved oxygen before treating a pond (Cornell, 1998). *Aquatic Life*: Copper sulfate is highly toxic to fish. It may be poisonous to trout and other fish, especially in soft or acidic waters, even when it is applied at recommended rates. Copper sulfate's toxicity to fish tends to decrease as water hardness increases. Fish eggs are more resistant to the toxic effects of copper sulfate than young fish fry. Copper sulfate is also toxic to aquatic invertebrates such as crabs, shrimp, and oysters (Extoxnet, 1996a). *Human Health*: The acute toxicity of copper sulfate is due largely to its being caustic. The lowest dose of copper sulfate that has been toxic when ingested by humans is 11 mg/kg. Ingestion of copper sulfate is often not toxic because vomiting is an automatic reflex of its irritation of the gastrointestinal tract. However, symptoms are severe if it is retained in the stomach. Symptoms include a burning pain in the chest and abdomen, intense nausea, repeated vomiting, diarrhea, headache, sweating, shock, and injury to the brain, liver, kidneys, and stomach (Extoxnet, 1996a). It may also irritate the skin and eyes (Syndel, 2001e). Copper sulfate has been shown to cause reproductive effects in test animals (Extoxnet, 1996a).
Diuron	Used to control algae.	*Fate in the Environment*: Diuron is moderately to highly persistent in soils and relatively stable in neutral water. Microbes are the primary agents in the degradation of diuron in water (Extoxnet, 1996b). When used properly, the chemical will not accumulate in pond bottom soils (Tucker and Leard, n.d.). *Aquatic Life*: Diuron is moderately toxic to fish and highly toxic to aquatic invertebrates. The LC_{50} (48-h) values for diuron range from 4.3 mg/L to 42 mg/L in fish and from 1 mg/L to 2.5 mg/L in aquatic invertebrates. The LC_{50} (96-h) for rainbow trout is 3.5 mg/L (Extoxnet, 1996b). *Human Health*: Diuron is slightly toxic to mammals. Animal studies indicate that it can cause increased mortality, growth retardation, abnormal blood pigment, anemia, and changes in the spleen, bone marrow, and blood chemistry (Extoxnet, 1996b). Diuron has been classified as a known/likely human carcinogen by all routes (USEPA, 1999b).

Chemical	***Use***	***Environmental Effects***
Acid blue and acid yellow (Aquashade)	Used to control vascular aquatic plants.	No environmental fate information was available. Aquashade is reported to be nontoxic to humans, livestock, and aquatic organisms (Washington Department of Ecology, 1994). Yet, it may cause eye and skin irritation, nausea, or gastric disturbances (Applied Biochemists, 1999). In a study that examined the effect of Aquashade on the oxygen consumption of crayfish, no effects were found at a concentration of 1 mg/L over 5 d (Danish Technological Institute, 1998).
Dichlobenil	Used to control vascular aquatic plants.	*Fate in the Environment*: Dichlobenil is persistent in water and groundwater and especially in soil. It has the potential to reach groundwater based on its water solubility, chemical structure, and use patterns. EPA requires a warning about this on labels of dichlobenil-containing products (Cox, 1997). Some formulations may not be labeled for commercial fish production ponds. Label instructions should be followed carefully (UGA, 2001). *Aquatic Life*: The acute toxicity of dichlobenil to fish under lab conditions varies, depending on the species and the length of exposure. Over a 10-d period, concentrations of less than 2 ppm killed fish. Rainbow trout are especially sensitive, with an LC_{50} of less than 5 ppm over 4 d. The LC_{50} for other species ranges from 6 to 16 ppm. In a field study in which small ponds were treated with dichlobenil, some fish developed tumors, inflamed kidney nodules, and reproductive problems. Dichlobenil can bioconcentrate in fish by a factor of 40 (Cox, 1997). The acute toxicity of dichlobenil on aquatic invertebrates varies widely among species. Sand fleas, water fleas, and stonefly nymphs are especially susceptible. Sublethal effects that can occur include a “narcotizing” effect on many invertebrates, gill irritation in damselflies, immobilization of caddisflies, and a loss of pigmentation in water boatmen. Aquatic invertebrates may also be affected indirectly when aquatic plants are killed and they have no place to hide (Cox, 1997). *Human Health*: Fish from treated waters should not be used for human consumption for 90 d following application (Riemer, 1984). Chronic exposure to dichlobenil may cause inactivity, loss of appetite, sedation, coma, or respiratory arrest (Information Ventures, 2000a). Exposure can also damage the olfactory system or cause eye and skin irritation. Animal studies show that long term exposure may result in liver nodules, kidney stones, reproductive effects, decreased weight gain, decreased food consumption, and increased liver and kidney weights. EPA has classified dichlobenil as a possible human carcinogen (Cox, 1997).

Chemical	Use	Environmental Effects
Diquat dibromide	Used to control vascular aquatic plants.	*Fate in the Environment*: Diquat dibromide is highly persistent in soil and ground water. Although it is water soluble, its capacity for strong adsorption to soil organic matter and clay suggest that it will not easily leach through the soil, be taken up by plants or soil microbes, or broken down by sunlight. When applied to open water, diquat dibromide disappears rapidly because it binds to suspended particles in the water. Diquat dibromide stays bound to these particles, remaining biologically inactive in surface waters. Its half life is less than 48 h in the water column. Microbial degradation and sunlight play roles in the breakdown of diquat dibromide in surface waters (Extoxnet, 1996c). *Aquatic Life*: Diquat dibromide is practically nontoxic to fish and aquatic invertebrates. The 8-h LC_{50} for diquat dibromide is 12.3 mg/L in rainbow trout and 28.5 mg/L in Chinook salmon. Research indicates that yellow perch suffer significant respiratory distress when herbicide concentrations in the water are similar to those normally present during aquatic vegetation control programs. There is little or no bioconcentration of diquat dibromide in fish (Extoxnet, 1996c). *Human Health*: Diquat dibromide is acutely toxic when absorbed through the skin and moderately toxic via ingestion. Ingestion of sufficient doses can cause severe irritation of the mouth, throat, esophagus, and stomach, followed by nausea, vomiting, diarrhea, severe dehydration, and alterations in body fluid balances, gastrointestinal discomfort, chest pain, kidney failure, and toxic liver damage. Very large doses can result in convulsions and tremors. Absorption of the herbicide from the gut into the bloodstream is low. Oral doses are metabolized within the intestines and then excreted in the feces. It is unlikely that diquat dibromide will cause reproductive effects in humans under normal circumstances (Extoxnet, 1996c).
Endothall	Used to control vascular aquatic plants.	*Fate in the Environment*: Endothall is highly mobile in soil; however, rapid degradation limits the extent of leaching. Endothall disappears from soil in 7–21 d. Its half-life is 4–5 d in clay soils and 9 d in soils with high organic content. Endothall is rapidly degraded in surface water, where its half-life is 4–7 d for dipotassium endothall and approximately 7 d for technical endothall. Biodegradation is slower without the presence of air (Extoxnet, 1995). *Aquatic Life*: Endothall is toxic to some species of fish. Inorganic salts of endothall in aquatic formulations are safe for fish in 100–500 ppm concentrations. However, amine salts of endothall are more toxic to fish than the dipotassium endothall. Endothall has a low toxicity to crustaceans and a medium toxicity to aquatic insects. Long term ingestion may cause severe damage to the digestive tract, liver, and testes in fish (Extoxnet, 1995). *Human Health*: Endothall is highly irritating to mucous membranes and precautions should be taken to keep it out of eyes, nose, mouth, and other sensitive areas (Riemer, 1984). Endothall is not classified as a carcinogen (Extoxnet, 1995).

Chemical	***Use***	***Environmental Effects***
Fluridone	Used to control vascular aquatic plants.	*Fate in the Environment*: Fluridone is moderately persistent in water and sediments following treatment. It is strongly adsorbed to organic matter in soil. Field tests have shown that the average half-life in pond water is 21 d and longer in sediments (90 d in hydrosoil). Residues may persist longer, depending on the amount of sunlight and the water temperature. Fluridone is stable to hydrolysis and it is primarily degraded by sunlight and microorganisms (DOH, 2000; Cornell, 1986). *Aquatic Life*: Fluridone does not significantly bioaccumulate or biomagnify in fish (DOH, 2000). Maximum Acceptable Theoretical Concentration (MATC) values indicate a potential hazard for aquatic organisms in shallow areas at higher treatment rates described on the label (Cornell, 1986). *Human Health*: Consumption of fish from treated water does not pose a threat to human health. Fluridone is not considered to be a carcinogen or mutagen (DOH, 2000).
Glyphosate	Used to control vascular aquatic plants.	*Fate in the Environment*: Glyphosate is not generally active in the soil and is not usually absorbed from the soil by plants. Its half-life in soil ranges from 3 to 130 d, depending on soil texture and organic content, and it is broken down by soil microorganisms. Glyphosate dissolves easily in water and its potential for leaching into ground water is low. The half-life of glyphosate in water ranges from 35 to 63 d (Information Ventures, 2000b). *Aquatic Life*: Glyphosate is practically nontoxic to fish and may be slightly toxic to aquatic invertebrates. The common glyphosate product is acutely toxic to fish. Acute toxicities of glyphosate vary widely due to differences in toxicity between the salts and the parent acid or to surfactants used in the formulation. There is a very low potential for glyphosate to bioaccumulate in aquatic invertebrates or other aquatic organisms (Extoxnet, 1996d). *Human Health*: Glyphosate can cause irritation of the eyes and skin, nausea, dizziness (Information Ventures, 2000b), low blood pressure, lung congestion or dysfunction, erosion of the gastrointestinal tract, and kidney damage or failure (Cox, 1995).

Chemical	***Use***	***Environmental Effects***
2, 4-D (acids, esters)	Used to control vascular aquatic plants.	*Fate in the Environment*: 2,4-D has low persistence in soil, with a half-life of less than 7 d. Soil microbes are primarily responsible for breaking it down. Despite its short half-life, 2,4-D has been detected in groundwater supplies in at least 5 states. Very low concentrations have also been detected in surface waters throughout the United States. In aquatic environments, 2,4-D is readily degraded by microorganisms. The rate of degradation increases with increased nutrients, sediment load, and dissolved organic carbon. The half-life of 2,4-D in water under oxygenated conditions is 1 wk to several weeks (Extoxnet, 1996e). *Aquatic Life*: Some formulations of 2,4-D are toxic to fish. Depending on the formulation used, the LC_{50} in cutthroat trout ranges between 1 and 100 mg/L. Channel catfish had less than 10% mortality when exposed to 10 mg/L for 48 h. Green sunfish showed no effect on swimming response when exposed to 110 mg/L for 41 h (Extoxnet, 1996e). *Human Health*: The human health criterion for 2,4-D, which is used to protect people from the carcinogenic risks of consuming water and/or organisms contaminated with 2,4-D, is 10 μg/L for consumption of water plus an organism. This indicates the concentration of 2,4-D that has a 10^{-6} risk of carcinogenicity (USEPA, 1999a). Symptoms of exposure to 2,4-D include nausea, eye irritation, central nervous system effects, gastrointestinal effects, vomiting, diarrhea, convulsions, coma, and liver and kidney damage. Exposure can also cause weakness, muscle twitching, headache, and fatigue. For additional symptoms, refer to NTP's Chemical Repository (NTP, n.d.). Due to conflicting study results, it is unclear whether 2,4-D is carcinogenic (Extoxnet, 1996e).
Antimycin	Used to kill fish.	Environmental fate information was unavailable. *Aquatic Life*: Antimycin is toxic to fish. Toxicity tests indicate that ruffe and brown trout are approximately five times more sensitive to antimycin than yellow perch (Boogaard et al., 1997). Antimycin should be applied when water temperatures are 60 °F or greater (Kentucky State University, n.d.). *Human Health*: Symptoms of acute exposure to Antimycin may include incoordination, impaired reflexes, respiratory distress, and central nervous system depression (USEPA, n.d.). Fish killed by antimycin are not approved for human or livestock consumption (Kentucky State University, n.d.).

Chemical	Use	Environmental Effects
Rotenone	Used to kill fish.	*Fate in the Environment*: The time for natural degradation of rotenone by hydrolysis is governed primarily by temperature. Studies show that rotenone completely degrades within 1 to 8 wk within the range of 10–20 °C. Its half life ranges from 13.9 h to 10.3 d for water temperatures of 24 °C and 5 °C, respectively. Rotenone dissipates quickly (less than 24 h) as a result of dilution and increased rates of hydrolysis and photolysis. Although it can be found in lake sediments, levels approximate those found in water and breakdown of rotenone lags 1 to 2 wk behind water levels. It is uncommon to find rotenone in stream sediments (AFS, 2000). *Aquatic Life*: Fish are more susceptible to rotenone than other aquatic animals. All animals have natural enzymes in the digestive tract that neutralize rotenone. However, fish are more susceptible because rotenone is readily absorbed into their blood through their gills, and thus digestive enzymes cannot neutralize it (AFS, 2000). *Human Health*: Research shows that rotenone does not cause birth defects, reproductive dysfunction, gene mutations, or cancer. When used according to label instructions, rotenone poses little if any hazard to public health. EPA has concluded that the use of rotenone for fish control does not present a risk of unreasonable adverse effects on humans and the environment (AFS, 2000).

6.6.4.5 Summary of Potential Impacts

Antibiotics and Antibiotic Resistance

A variety of antibiotics are heavily used in the CAAP industry, including oxytetracycline, sulfadimethoxine, and sulfamerazine. Effluents produced from these facilities can contain not only appreciable concentrations of the antibiotics themselves but also a variety of bacterial species, some of which are antibiotic-resistant. These antibiotic-resistant strains of bacteria have the potential to confer antibiotic resistance to the resident bacteria in the guts of humans, along with native aquatic bacteria species that are found in the effluent release areas. Many bacteria in aquatic environments have a pronounced capacity for acquisition and transfer of resistance genes. The route of transmission from animals to humans by meat products is well established. The transfer of antibiotic resistance from fish to humans by fish consumption is not as well studied, but it is presumed to occur at the same rates. To assess the impacts of antibiotics and antibiotic resistance on public health, animal health, and ecosystem health, some basic assessments of the types and concentrations of antibiotics used will be necessary to determine whether CAAP effluents should be monitored for excess antibiotics or antibiotic-resistant bacterial species (particularly those that represent a public health risk).

Biological Impairment

One of the most difficult to quantify, and potentially most dangerous, impacts of CAAP effluents is biological impairment. Effluents from CAAP facilities can contain a range of altered species, including antibiotic-resistant microorganisms and escaped organisms. In addition, the dangers of the added drugs and chemicals used for increased production are not well known. Extensive surveys of the amounts and types of chemicals used in aquaculture facilities is necessary, along with an understanding of the impacts of these drugs and chemicals on the surrounding ecosystems.

Another area of acute concern is invasive species introduction from CAAP facilities, which poses serious potential and observed risks to native fishery resources and wild native aquatic species from the establishment of escaped individuals (Carlton, 2001; Hallerman and Kapuscinski, 1992; Volpe et al., 2000). In some regions of the United States, ecological and natural resource threats associated with invasive species are among the most critical concerns facing environmental protection agencies. A particular concern is a potentially higher risk of adverse impacts on native populations that might arise from the introduction of genetically modified organisms ("transgenic organisms"), which are being contemplated for use in this industry (Hedrick, 2001). CAAP facilities also employ a range of drugs and chemicals used both therapeutically that may be released into receiving waters. The absence of adequate information on potential risks to ecosystems and possibly to human health from the consumption of organisms inadvertently exposed to these substances after their release into the environment has led to regulatory action at the regional level to prohibit certain drug and chemical applications (USEPA, 2002a). Finally, CAAP facilities also may inadvertently introduce pathogens into receiving waters, with potentially serious adverse impacts on native biota.

6.7 References

AFS (American Fisheries Society). 1997. *Resource Policy Handbook: Introduction of Aquatic Species.* American Fisheries Society. <http://www.fisheries.org/resource/page13.htm>. Accessed January 2002.

AFS (American Fisheries Society). 2000. *Rotenone Use in Fisheries Management: Administrative and Technical Guidelines Manual*. American Fisheries Society. <http://www.fisheries.org/rotenone/Rotenone_Manual.pdf>. Accessed May 2001.

Alverson, D.L., and G.T. Ruggerone. 1998. *Escaped Farm Salmon: Environmental and Ecological Concerns*. Environmental Assessment Office, Government of British Columbia. <http://www.eao.gov.bc.ca/PROJECT/AQUACULT/SALMON/Report/final/vol3/vol3-b.htm>. Accessed March 2002.

Applied Biochemists. 1999. *Material Safety Data Sheet: Aquashade*. <http://www.aplliedbiochemists.com/aqshmsds.pdf>. Accessed May 2001.

ATSDR (Agency for Toxic Substances and Disease Registry). 1990. *Public Health Statement: Copper*. Agency for Toxic Substances and Disease Registry. <http://www.atsdr.cdc.gov/ToxProfiles/phs9008.html>. Accessed October 2000.

AQUI-S, New Zealand Ltd. 1998. *AQUI-S*. <http://www.aqui_s.com>. Accessed May 2001.

Bain, M.B. 1993. Assessing Impacts of Introduced Aquatic Species: Grass Carp in Large Systems. *Environmental Management* 17(2):211-224.

Blazer, V.S., and S.E. LaPatra. 2002. Pathogens of Cultured Fishes: Potential Risks to Wild Fish Populations. In *Aquaculture and the Environment in the United States*, ed.

J. Tomasso. pp. 197-224. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Boardman, G.D., V. Maillard, J. Nyland, G.J. Flick, and G.S. Libey. 1998. *The Characterization, Treatment, and Improvement of Aquacultural Effluents.* Departments of Civil and Environmental Engineering, Food Science and Technology, and Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Boogaard, M.A., T.D. Bills, J.H. Selgeby, and D.A. Johnson. 1997. *Evaluation of Piscicides for Control of Ruffe*. U.S. Geological Survey, U.S. Fish and Wildlife Service.

Boyd, C.E. 2000. Farm Effluent During Draining for Harvest. *The Global Aquaculture Advocate* (August):26-27.

Boyd, C.E., and C.S. Tucker. 1998. *Pond Aquaculture Water Quality Management*. pp. 541-575. Kluwer Academic Publishers, Norwell, MA.

Boyd, C.E., J. Queiroz, J.-Y. Lee, M. Rowan, G. Whitis, and A. Gross. 2000. Environmental Assessment of Channel Catfish (*Ictalurus punctatus*) Farming in Alabama. *Journal of the World Aquaculture Society* 31:511-544.

Carlton, J.T. 2001. *Introduced Species in U.S. Coastal Waters. Environmental Impacts and Management Priorities*. Prepared for the Pew Oceans Commission, Arlington, VA.

CDC (Centers for Disease Control and Prevention). n.d. *International Chemical Safety Cards: Urea*. Centers for Disease Control and Prevention. <http://www.cdc.gov/niosh/ipcsneng/neng0595.html>. Accessed May 2001.

Chen, S., S. Summerfelt, T. Losordo, and R. Malone. 2002. Recirculating Systems, Effluents, and Treatments. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 119-140. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Chilton, E.W., and M.I. Muoneke. 1992. Biology and Management of Grass Carp (*Ctenopharyngodon idella*, Cyprinidae) for Vegetation Control: a North American Perspective. Reviews in *Fish Biology and Fisheries* 2:283-320. In USGS, 2001. *Nonindigenous Fishes* – Ctenopharyngodon idella. <http://www.nas.er.usgs.gov/fishes/accounts/cyprinid/ct_idell.html>. Accessed March 2002.

Cornell. 1986. *Fluridone Herbicide Profile*. Cornell University, Ithaca. <http://www.pmep.cce.cornell.edu/profiles/herb_growthreg/fatty_alcohol_monuron/fluridone/herb_prof_fluridone.html>. Accessed May 2001.

Cornell. 1998. *Treatment of Diseased Fish*. Cornell University, Cornell Veterinary Medicine, Ithaca. <http://web.vet.cornell.edu/public/FishDisease/resources/diagnostics/treatment.htm>. Accessed May 2001.

Courtenay, W.R., Jr., D.A. Hensley, J.N. Taylor, and J.A. McCann. 1984. Distribution of Exotic Fishes in the Continental United States. In *Distribution, Biology and Management of Exotic Fishes,* ed. W.R. Courtenay, Jr., and J.R. Stauffer, Jr., pp. 41-77. Johns Hopkins University Press, Baltimore, MD.

Courtenay, W.R., Jr., and J.D. Williams. 1992. Dispersal of Exotic Species from Aquaculture Sources, with Emphasis on Freshwater Fishes. In *Dispersal of Living Organisms into Aquatic Ecosystems*, ed. A. Rosenfield, and R. Mann, pp. 49-81. Maryland Sea Grant Publication, College Park, MD.

Cox, C. 1995. Glyphosate Fact Sheets: Part 1 and Part 2. *Journal of Pesticide Reform* 15(3). <http://www.usfumigation.org/Literature/Scientific%20Papers/glyphosate_fact_sheets.htm>. Accessed May 2001.

Cox, C. 1997. Herbicide Factsheet: Dichlobenil. *Journal of Pesticide Reform,* Spring. <http://www.pesticide.org/dichlobenil.pdf>. Accessed May 2001.

Danish Technological Institute. 1998. *Survey of Azo-Colorants in Denmark: Consumption, Use, Health, and Environmental Aspects*. Danish Environmental Protection Agency, Denmark. <http://www.mst.dk/udgiv/publications/1999/87_7909_548_8/pdf/87_7909_546_1.pdf>. Accessed May 2001.

Delos Reyes, Jr., A.A., R.F. Malone, S.J. Langlinias, J.V. Huner, R. Soileau, and K.A. Rusch. 1996. Energy Conservation and Environmental Improvement in an Intensive Recirculating Alligator Production System. In *Successes and Failures in Commercial Recirculating Aquaculture,* vol. II. pp. 494-506. National Regional Agricultural Engineering Service, Ithaca, NY.

Dentler, J.L. 1993. Noahs Farce: The Regulation and Control of Exotic Fish and Wildlife. *University of Puget Sound Law Review* 17:191-242.

Dill, W. A., and A.J. Cordone. 1997. *History and Status of Introduced Fishes in California, 1871-1996*. Manuscript for Fish Bulletin of the California Department of Fish and Game 178, pp. 223-226. California Department of Fish and Game, Sacramento, CA.

DOH (Department of Health). 2000. *Fluridone (Sonar)*. Washington State Department of Health. <http://www.sepro.com/pdf_lit/Aquatics/sonar/fluridone_fact_sheet.pdf>. Accessed May 2001.

Dubos, R.J. 1955. Second Thoughts on Germ Theory. *Scientific American* 192:31-35.

EAO (Environmental Assessment Office). 1997. Impacts of Farmed Salmon Escaping from Net Pens. Environmental Assessment Office, Government of British Columbia. <http://www.eao.gov.bc.ca/project/aquacult/salmon/escape.htm>. Accessed March 2002.

Extoxnet. 1995. *Pesticide Information Profiles: Endothall*. Extension Toxicology Network, a cooperative effort of the University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of

Idaho. <http://www.ace.ace.orst.edu/info/extoxnet/pips/endothal.htm>. Accessed May 2001.

Extoxnet. 1996a. *Pesticide Information Profiles: Copper Sulfate*. Extension Toxicology Network, a cooperative effort of the University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. <http://www.ace.ace.orst.edu/info/extoxnet/pips/coppersu.htm>. Accessed May 2001.

Extoxnet. 1996b. *Pesticide Information Profiles: Diuron*. Extension Toxicology Network, a cooperative effort of the University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. <http://ace.ace.orst.edu/info/extoxnet/pips/diuron.htm>. Accessed May 2001.

Extoxnet. 1996c. *Pesticide Information Profiles: Diquat Dibromide*. Extension Toxicology Network, a cooperative effort of the University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. <http://ace.ace.orst.edu/info/extoxnet/pips/diquatdi.htm>. Accessed May 2001.

Extoxnet. 1996d. *Pesticide Information Profiles: Glyphosate*. Extension Toxicology Network, a cooperative effort of the University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. <http://ace.ace.orst.edu/info/extoxnet/pips/glyphosa.htm>. Accessed May 2001.

Extoxnet. 1996e. *Pesticide Information Profiles: 2,4-D*. Extension Toxicology Network, a cooperative effort of the University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. <http://ace.ace.orst.edu/info/extoxnet/pips/24-D.htm>. Accessed May 2001.

FDA (Food and Drug Administration). 1996. *Freedom of Information Summary: NADA 008-804*. <http://www.fda.gov/cvm/efoi/section1/008804s031496.html>. Accessed May 2001.

FDA (Food and Drug Administration). 1997. NRSP-7 Holds Semi-Annual Committee.Meeting. *FDA Veterinarian Newsletter* 12 (November/ December). <http://www.fda.gov/cvm/index/fdavet/1997/november.htm>. Accessed May 2001.

FDA (Food and Drug Administration). 1998. NRSP Holds Semi-Annual Committee. Meeting. *FDA Veterinarian Newsletter* 13 (November/ December). <http://www.fda.gov/cvm/index/fdavet/1998/november.htm>. Accessed May 2001.

FDA (Food and Drug Administration). 1999. *Freedom of Information Summary: NADA 140-927*. <http://www.fda.gov/cvm/efoi/section2/140927s080699.html>. Accessed May 2001.

FDA (Food and Drug Administration). 2002. *Drugs Approved for Use in Aquaculture (Poikilothermic Food Species)*. <http://www.fda.gov/cvm/index/ aquaculture/appendixa6.htm>. Accessed August 2002.

FDA (Food and Drug Administration). n.d.a. *Parasite-S NADA 140-989: General Information*. <http://www.fda.gov/cvm/efoi/section2/140989.pdf>. Accessed May 2001.

FDA (Food and Drug Administration). n.d.b. *Freedom of Information Summary Abbreviated New Animal Drug Application (ANADA) 200-226*. <http://www.fda.gov/cvm/efoi/section3/200226112197.html>. Accessed May 2001.

FDA (Food and Drug Administration). n.d.c. *Extramural Research*. <http://www.fda.gov/cvm/index/aquaculture/osextra.htm>. Accessed May 2001.

Faust, R.A. 1992. *Toxicity Summary for Copper*. Oak Ridge Reservation Environmental Restoration Program. <http://www.risk.lsd.ornl.gov/tox/ profiles/copper.shtml>. Accessed October 2000.

Font, W.F., and D.C. Tate. 1994. Helminth Parasites of Native Hawaiian Freshwater Fishes: An Example of Extreme Ecological Isolation. *Journal of Parasitology* 80:682-688.

Fuller, P.L., L.G. Nico, and J.D. Williams. 1999. *Nonindigenous Fishes Introduced into Inland Waters of the United States.* Special publication no. 27. *American Fisheries Society*, Bethesda, MD.

Ganzhorn, J., J. S. Rohovec, and J. L. Fryer. 1992. Dissemination of Microbial Pathogens through Introductions and Transfers of Finfish. In *Dispersal of Living Organisms into Aquatic Ecosystems*, ed. A. Rosenfield and R. Mann, pp. 175-192. Maryland Sea Grant, College Park, MD. In USGS, 2001. *Nonindigenous Fishes – Ctenopharyngodon idella*. <http://www.nas.er.usgs.gov/fishes/accounts/cyprinid/ct_idell.html>. Accessed March 2002.

GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). 1997. Towards Safe and Effective Use of Chemicals in Coastal Aquaculture. IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. Reports and Studies GESAMP. No. 65. London, IMO. 40 pp. <http://www.fao.org/docrep/meeting/003/w6435e.htm>. Accessed October 2001.

Grubbs, G. 2001, November 14. Memorandum to Regions I – X Water Directors, State Water Programs Directors, Great Water Body Programs Directors, Authorized Tribal Water Quality Standards Programs Directors, and State and Interstate Water Pollution Control Administrators. *Development and Adoption of Nutrient Criteria into Water Quality Standards*. U.S. Environmental Protection Agency. <http://www.epa.gov/waterscience/criteria/nutrientswqsmemo.pdf>. Accessed December 2001.

Halamid. n.d. *Halamid, Aquaculture*. <http://www.halamid.com/aqua.htm>. Accessed May 2001.

Hallerman, E.M., and A.R. Kapuscinski, 1992. Ecological Implications of Using Transgenic Fishes in Aquaculture. *ICES March Science Symposium* 194:56-66.

Hargreaves, J.A., C.E. Boyd, and C.S. Tucker. 2002. Water Budgets for Aquaculture Production. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 9-34. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Hedrick, P.W. 2001. Invasion of Transgenes from Salmon or other Genetically Modified Organisms into Natural Populations. *Canadian Journal of Fisheries and Aquatic Science* 58(2001):841-844.

Henry, J.G., and G.W. Heinke. 1996. *Environmental Science and Engineering*. 2d ed. pp. 327-328. Prentice-Hall, Inc., Upper Saddle River, NJ.

Hinshaw, J.M., and G. Fornshell. 2002. Effluents from Raceways. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 77-104. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Hodson, R.G., and J. Jarvis. 1990. *Raising Hybrid Striped Bass in Ponds*. University of North Carolina Sea Grant College Program, Raleigh, NC.

Hoffman, G.L., and G. Schubert. 1984. Some Parasites of Exotic Fishes. In *Distribution, Biology, and Management of Exotic Fishes*, ed. W.R. Courtenay, Jr., and J.R. Stauffer, Jr., pp. 233-261. The Johns Hopkins University Press, Baltimore, MD.

IDEQ (Idaho Department of Environmental Quality). n.d. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

Information Ventures. 2000a. *Dichlobenil Pesticide Fact Sheet*. Prepared for the U.S. Department of Agriculture. <http://www.infoventures.com/ehlth/pesticide/dichlobe.html>. Accessed May 2001.

Information Ventures, Inc. 2000b. *Glyphosate Pesticide Fact Sheet*. Prepared for the U.S. Department of Agriculture, Forest Service. <http://www.infoventures.com/e-hlth/pestcide/glypho.html>. Accessed May 2001.

Iversen, E.S., D.M. Allen, and J.B. Higman. 1993. *Shrimp Capture and Culture Fisheries in the United States*. Halsted Press, an imprint of John Wiley and Sons, Inc., NY.

J.T. Baker. 1998. *Material Safety Data Sheet: Calcium Oxide*. <http://www.jtbaker.com/msds/c0462.htm>. Accessed May 2001.

J.T. Baker. 1999a. *Material Safety Data Sheet: Calcium Chloride*. <http://www.jtbaker.com/cgi_bin/msds_s.pl?searchdata=1311>. Accessed May 2001.

J.T. Baker. 1999b. *Material Safety Data Sheet: Urea*. <http://www.jtbaker.com/msds/u4725.htm>. Accessed May 2001.

J.T. Baker. 2001. *Material Safety Data Sheet: Acetic Acid Glacial*. <http://www.jtbaker.com/cgi_bin/msds_s.pl?searchdata=9508>. Accessed May 2001.

JSA (Joint Subcommittee on Aquaculture) Shrimp Virus Work Group. 1997. *An Evaluation of Potential Shrimp Virus Impacts on Cultured Shrimp and Wild Shrimp Populations in the Gulf of Mexico and Southeastern U.S. Atlantic Coastal Waters*. A report to the Joint Subcommittee on Aquaculture prepared by the JSA Shrimp Virus Work Group, Washington, DC.

JSA (Joint Subcommittee on Aquaculture). 2000. *Effluents from Catfish Aquaculture Ponds*. Prepared by the Technical Subgroup for Catfish Production in Ponds, Joint Subcommittee on Aquaculture, Washington, DC.

Kaufman, D.G., and C.M. Franz. 1993. *Biosphere 2000: Protecting Our Global Environment*. Harper Collins College Publishers, NY.

Kendra, W. 1991. Quality of Salmon Hatchery Effluents During a Summer Low-Flow Season. *Transactions of the American Fisheries Society* 120:43-51.

Kentucky State University. n.d. *Removal of Undesirable Fishes from Warmwater Ponds*. Kentucky State University Cooperative Extension Program. <http://aquanic.org/publicat/state/ky/unwanted.pdf>. Accessed May 2001.

Kohler, C.C., and W.R. Courtenay. n.d. *American Fisheries Society Position on Introductions of Aquatic Species*. American Fisheries Society, Introduced Fish Section. <http://www.afsifs.vt.edu/afspos.html>. Accessed January 2002.

Lawson, T.B. 1995. *Fundamentals of Aquacultural Engineering*. pp. 48-57. Chapman & Hall, NY.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980 et seq. *Atlas of North American Freshwater Fishes*. North Carolina State Museum of Natural History, Raleigh, NC. (Cited as the complete work rather than as individual accounts in the interest of space).

Loch, J.J., and S.A. Bonar. 1999. Occurrence of Grass Carp in the Lower Columbia and Snake Rivers. *Transactions of the American Fisheries Society* 128:374-379.

Losordo, T.M., and M.B. Timmons. 1994. An Introduction to Water Ruse Systems. In *Aquaculture Reuse Systems: Engineering Design and Management*. pp. 1-7. Elsevier Science, Amsterdam, The Netherlands.

LSU (Louisiana State University). 1999. *Crawfish Production Manual*. Publication no. 2637. Louisiana State University, Agricultural Center, Louisiana Cooperative Extension Service, Baton Rouge, LA.

Lutz, G. 2001. Best Waste Management Practices for the Alligator, Crawfish, and Turtle Industries. Paper presented at the Aquaculture Waste Management Symposium, July 22-24, 2001.

MacMillan, J.R., R. Reimschuessel, B.A. Dixon, G.J. Flick, and E.S. Garrett. 2002. *Aquaculture Effluents and Human Pathogens: A Negligible Impact*. The Human Pathogens and Aquaculture Effluent Special Subgroup. Submitted to the JSA Aquaculture Effluents Task Force, 8 pp.

McAllister, P.E. 1990. *Fish Disease Leaflet 83: Viral Hemorrhagic Septicemia of Fishes*. Department of the Interior, U.S. Fish and Wildlife Service, Washington, DC, National Fisheries Research Center–Leetown, National Fish Health Research Laboratory. <http://www.lsc.nbs.gov/fhl/FDL83.HTM>. Accessed March 2002.

Meyer, F.P. 1970. Seasonal Fluctuations in the Incidence of Disease on Fish Farms. In *A Symposium on Diseases of Fishes and Shell Fishes*, ed. S.F. Snieszko. special publication no. 5, American Fishery Society, Washington, DC.

Murphy, S. 2000a. *General Information on Nitrogen*. Boulder Area Sustainability Information Network (BASIN). <http://www.bcn.boulder.co.us/basin/data/FECAL/info/NO3+NO2.html>. Accessed December 2001.

Murphy, S. 2000b. *General Information on Phosphorus*. Boulder Area Sustainability Information Network (BASIN). <http://www.bcn.boulder.co.us/basin/data/FECAL/info/OP_Dis.html>. Accessed December 2001.

Murphy, S. 2000c. *General Information on Solids*. Boulder Area Sustainability Information Network (BASIN). <http://www.bcn.boulder.co.us/basin/data/FECAL/info/TSS.html>. Accessed December 2001.

New Jersey. 1996. *Calcium Oxide*. <http://www.state.nj.us/health/eoh/rtkweb/0325.pdf>. Accessed May 2001.

New Jersey. 1998. *Hydrogen Peroxide*. <http://www.state.nj.us/health/eoh/rtkweb/1015.pdf>. Accessed May 2001.

NTP (National Toxicology Program). 1991a. *NTP Chemical Repository: Acetic Acid*. National Toxicology Program, National Institute of Environmental Health Sciences, National Institutes of Health. <http://157.98.13. 224/NTP_Reports/NTP_Chem_H&S/NTP_Chem6/Radian64-19-7.txt>. Accessed May 2001.

NTP (National Toxicology Program). 1991b. *NTP Chemical Repository: Hydrogen Peroxide*. National Toxicology Program, National Institute of Environmental Health Sciences, National Institutes of Health. <http://www.157.98.13.224/NTP_Reports/NTP_Chem_H&S/NTP_Chem7/Radian7722-84-1.txt>. Accessed May 2001.

NTP (National Toxicology Program). 1991c. *NTP Chemical Repository: Potassium Chloride*. National Toxicology Program, National Institute of Environmental Health Sciences, National Institutes of Health. <http://157.98.13.224/NTP_Reports/NTP_Chem_H&S/NTP_Chem7/Radian7447-40-7.txt>. Accessed May 2001.

NTP (National Toxicology Program). 1991d. *NTP Chemical Repository: Urea*. National Toxicology Program, National Institute of Environmental Health Sciences, National Institutes of Health. <http://ntp_db.niehs.nih.gov/NTP_Reports/NTP_Chem_H&S/NTP_Chem5/Radian57_13_6.txt>. Accessed May 2001.

NTP (National Toxicology Program). n.d. *NTP Chemical Repository: 2,4-Dichlorophenoxyacetic Acid*. National Toxicology Program, National Institute of Environmental Health Sciences, National Institutes of Health. <http://www.ntp-

server.niehs.nih.gov/htdocs/Chem_H&S/NTP_Chem9/Radian94-75-7.html>. Accessed May 2001.

Nussey, G., J.H.J. van Vuren, and H.H. du Preez. 1995. Effect of Copper on the Hematology and Osmoregulation of the Mozambique tilapia (*Oreochromis mossambicus*) (Cichlidae). *Comparative Biochemistry and Physiology* 111C(3):369-380.

Orellana, F.X. 1992. Characterization of Effluents from Commercial Crawfish Ponds in Southern Louisiana. M.S. Thesis. Louisiana State University, Baton Rouge, LA.

Pardue, J.H., R.D. DeLaune, and W.H. Patrick, Jr., and J.A. Nyman. 1994. Treatment of Alligator Farm Wastewater Using Land Application. *Aquacultural Engineering* 13:129-45.

Pflieger, W.L. 1975. *The Fishes of Missouri*. pp. 129-130. Missouri Department of Conservation, Jefferson City, MO.

ProSciTech. 1998. *Material Safety Data Sheet: Tannic Acid*. <http://www.proscitech.com/ au/msds/c081.htm>. Accessed May 2001.

Rakocy, J.E., T.M. Losordo, and M.P. Masser. 1992. *Recirculating Aquaculture Tank Production Systems: Integrating Fish and Plant Culture.* SRAC publication no. 454. Southern Regional Aquaculture Center, Stoneville, MS.

Riemer, D. 1984. *Introduction to Freshwater Vegetation,* pp. 153-155. Avi Publishing Company, Inc., Westport, CT.

Rose, S. 1972. What About the White Amur? A Superfish or a Supercurse*? Florida Naturalist* (October):156-157.

Schueler, T.R., and H.K. Holland. 2000. *The Practice of Watershed Protection*. pp. 64-65. Center for Watershed Protection, Ellicott City, MD.

Scudder, B.C., J.L. Carter, and H.V. Leland. 1988. Effects of Copper on the Development of the Fathead Minnow (*Pimephales promelas* Rafinesque). *Aquatic Toxicology* 12:107-124.

Shireman, J.V., and C. R. Smith. 1983. *Synopsis of Biological Data on the Grass Carp* Ctenopharyngodon idella *(Cuvier and Valenciennes, 1844).* FAO Fisheries Synopsis no. 135. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 86 pp.

Shirley, M. 2002. Louisiana Cooperative Extension Service. Personal communication, May 14, 2002.

Stickney, R.R. 2000. Tilapia Culture. In *Encyclopedia of Aquaculture*, ed., R.R. Stickney, pp. 934-941. John Wiley and Sons, Inc., NY.

Stickney, R.R. 2002. Impacts of Cage and Net Pen Culture on Water Quality and Benthic Communities. In *Aquaculture and the Environment in the United States*, ed.

J. Tomasso, pp. 105-118. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Stone, N., H. Thomforde, and E. Park. n.d. *Baitfish Production in Ponds*. Prepared for U.S. Environmental Protection Agency by the Technical Subgroup of the Joint Subcommittee on Aquaculture, Aquaculture Effluent Task Force, Washington, DC.

Syndel. 2001a. *Material Safety Data Sheet: Calcium Chloride*. Syndel International, Inc. <http://www.syndel.com/msds/calcium_chloride_msds.html>. Accessed May 2001.

Syndel. 2001b. *Material Safety Data Sheet: Ovadine*. Syndel International, Inc. <http://www.syndel.com/msds/ovadine_msds.html>. Accessed May 2001.

Syndel. 2001c. *Material Safety Data Sheet: Sodium Chloride*. Syndel International, Inc. <http://www.syndel.com/msds/nacl_msds.html>. Accessed May 2001.

Syndel. 2001d. *Material Safety Data Sheet: Sodium Sulfite*. Syndel International, Inc. <http://www.syndel.com/msds/sodium_sulfite_msds.html>. Accessed May 2001.

Syndel. 2001e *Material Safety Data Sheet: Copper Sulfate*. Syndel International, Inc. <http://www.syndel.com/msds/copper_sulfate_msds.html>. Accessed May 2001.

Syndel. 2001f. *Material Safety Data Sheet: Ovaplant*. Syndel International, Inc. <http://www.syndel.com/msds/ovaplant _msds.html>. Accessed May 2001.

Syndel. 2001g. *Material Safety Data Sheet: Ovaprim*. Syndel International, Inc. <http://www.syndel.com/msds/ovaprim _msds.html>. Accessed May 2001.

Syndel. 2001h. *Ovaplant*. Syndel International, Inc. <http://www.syndel.com/ spawning/ovaprim_information_sheet.html>. Accessed May 2001.

Syndel. 2001i. *Ovaprim*. Syndel International, Inc. <http://www.syndel.com/ spawning/ovaplant_information_sheet.html>. Accessed May 2001.

Syndel. 2001j. *Material Safety Data Sheet: Potassium Permanganate*. Syndel International, Inc. <http://www.syndel.com/ msds/potassium_permanganate_msds.html>. Accessed May 2001.

Taylor, J. N., W.R. Courtenay, Jr., and J.A. McCann. 1984. Known Impact of Exotic Fishes in the Continental United States. In *Distribution, Biology, and Management of Exotic Fish*, ed. W.R. Courtenay, Jr., and J.R. Stauffer, pp. 322-373. Johns Hopkins Press, Baltimore, MD.

TEC (Total Environment Centre). 1998. *Copper*. Total Environment Centre, Nature Conservation Council. <http://www.tec.nccnsw.org.au/member/tec/ projects/tcye/tox/Copper.html>. Accessed October 2000.

Tetra Tech, Inc. 2002, August. Site visit report for Harlingen Shrimp Farm, Arroyo Aquaculture Association, and Loma Alta, Los Fresnos, TX.

Treece, G.D. 2000. Shrimp Culture. In *Encyclopedia of Aquaculture*, ed. R.R. Stickney, pp. 798-868. John Wiley and Sons, Inc., NY.

Tucker, C.S., ed. 1998. *Characterization and Management of Effluents from Aquaculture/ Ponds in the Southern United States*. SRAC final report no. 600. Southern Regional Aquaculture Center, Stoneville, MS.

Tucker, T.S., and A.T. Leard. n.d. *Managing Catfish Off-Flavors with Diuron*. Thad Cochran National Warmwater Aquaculture Center, Stoneville, MS.

UGA (University of Georgia). 2001. *Georgia Pest Control Handbook: Aquatic Weed Control*. University of Georgia, Entomology. <http://www.ent.uga.edu/pest2001/Aquatic/Weed_Control.htm>. Accessed May 2001.

UMN (University of Minnesota). 2000. *A Field Guide to Aquatic Exotic Plants and Animals*. University of Minnesota, Minnesota Sea Grant Program. <http://www.seagrant.umn.edu/exotics/fieldguide.html>. Accessed January 2002.

University of Delaware. 1995. *Exotic Species Watch: News About Non-Native Aquatic Plants and Animals of Concern to Delaware*. University of Delaware Sea Grant College Program. <http://www.sgnis.org/publicat/newsltr/w95.pdf>. Accessed March 2002.

USDA (U.S. Department of Agriculture). 2002. *Infectious Anemia Program Standards*. U.S. Department of Agriculture, Animal and Plan Health Inspection Service, Veterinary Service, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1985. *Ambient Water Quality Criteria for Copper — 1984.* EPA 440/5-84-031. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999a. *National Recommended Water Quality Criteria - Correction*. U.S. Environmental Protection Agency. <http://www.epa.gov/ost/pc/revcom.pdf>. Accessed May 2001.

USEPA (U.S. Environmental Protection Agency). 1999b. *Federal Register Document: Diuron*. U.S. Environmental Protection Agency. <http://www.epa.gov/fedrgstr/EPA-PEST/1999/July/Day-30/p19591.htm>. Accessed May 2001.

USEPA (U.S. Environmental Protection Agency). 2000. *National Water Quality Inventory: 1998 Report to Congress*. EPA 841-R-00-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC. <http://www.epa.gov/305b/98report/toc.html>. Accessed December 2001.

USEPA (U.S. Environmental Protection Agency). 2002a. National Pollutant Discharge Elimination System Permit no. ME0036234, issued to Acadia Aquaculture, Inc. Signed February 21, 2002.

USEPA (U.S. Environmental Protection Agency). 2002b. National Pollutant Discharge Elimination System Permit no. ID-G13-0000, U.S. Environmental Protection Agency, Region 10, Seattle, WA.

USEPA (U.S. Environmental Protection Agency). n.d. *Emergency First Aid Treatment Guide for Antimycin A*. U.S. Environmental Protection Agency. <http://www.epa.gov/swercepp/ehs/firstaid/1397940.txt>. Accessed May 2001.

USGS (U.S. Geological Survey). 2000a. *Nonindigenous Fishes* — Oreochromis aureus. United States Geological Survey, Nonindigenous Aquatic Species. <http://www.nas.er.usgs.gov/fishes/accounts/cichlida/or_aureu.html>. Accessed March 2002.

USGS (U.S. Geological Survey). 2000b. *Nonindigenous Fishes* — Oreochromis mossambicus. United States Geological Survey, Nonindigenous Aquatic Species. <http://www.nas.er.usgs.gov/fishes/accounts/cichlida/or_mossa.html>. Accessed March 2002.

USGS (U.S.Geological Survey). 2001. *Nonindigenous Fishes* — Ctenopharyngodon idella. United States Geological Survey, Nonindigenous Aquatic Species. <http://www.nas.er.usgs.gov/fishes/accounts/cyprinid/ct_idell.html>. Accessed March 2002.

Volpe, J.P., E.B. Taylor, D.W. Rimmer, and B.W. Glickman. 2000. Evidence of Natural Reproduction of Aquaculture-Escaped Atlantic Salmon in a Coastal British Columbia River. *Conservation Biology* 14(3 June 2000):899-903.

Washington Department of Ecology. 1994. *A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans.* Appendix D. *Aquatic Plant Control Methods*. Washington State Department of Ecology. <http://www.ecy.wa.gov/pubs/93093.pdf>. Accessed May 2001.

Watson, C.A. 2002. University of Florida. Personal communication, February 2, 2002.

Wheaton, F.W. 1977a. *Aquacultural Engineering*, pp. 229-247. John Wiley and Sons, Inc., NY.

Wheaton, F.W. 1977b. *Aquacultural Engineering*, pp. 643-679. John Wiley and Sons, Inc., NY.

Whetstone, J. 2002. Clemson University, Clemson, SC. Personal communication, April 11, 2002.

CHAPTER 7
BEST MANAGEMENT PRACTICES AND TREATMENT TECHNOLOGIES CONSIDERED FOR THE CONCENTRATED AQUATIC ANIMAL PRODUCTION INDUSTRY

7.1 INTRODUCTION

Best management practices (BMPs) are management strategies and practices that concentrated aquatic animal production (CAAP) facility operators use to increase production efficiencies while reducing either the effluent volume or concentrations of pollutants in the effluent stream. Examples of BMPs include feed management, health management, and mortality removal. Wastewater treatment technologies are used at a facility to remove one or more pollutants from the effluent stream. For example, primary settling of solids is a technology used at a facility to capture solids from the facility's effluent. EPA evaluated a variety of BMPs and treatment technologies, which are described in this chapter, currently used in the CAAP industry, as well as some used in other industries. Because each production system discharges effluents with different characteristics, EPA considered the treatment technologies and practices discussed in this chapter throughout the development of the ELGs. EPA further evaluated some of these technologies and practices as part of the regulatory options that may apply the technology or practice. The production systems listed at the end of each technology or BMP description indicates which systems may apply to the technology or practice discussed.

7.2 BEST MANAGEMENT PRACTICES

7.2.1 Feed Management

Feed is the primary source of pollutants to CAAP systems. Feed management recognizes the importance of effective, environmentally sound use of feed. Facility operators should continually evaluate their feeding practices to ensure that feed is consumed at the highest rate possible. For pond systems, pond biomass, though difficult to estimate accurately, can be helpful in determining how much feed to add to a particular pond. For all systems, observing feeding behavior and noting the presence of excess feed can be used to adjust feeding rates to ensure maximum feed consumption and minimal excess.

The primary operational factors associated with proper feed management are development of feeding regimes, based on the weight of the cultured species, and regular observation of feeding activities to ensure that the feed is consumed. This practice is advantageous because it decreases the costs associated with excess feed that is not consumed by the cultured species. Excess feed can degrade the quality of the production water by adding excess nutrients to the system. Facilities should also handle and store feed with care to prevent the breakdown of feed into fine particles. If fines are present in the feed, they should be removed and disposed of properly.

In pond systems, solids from the excess feed usually settle out and are naturally processed, along with feces from the aquatic animals. Although most of the dissolved and solids fractions from the uneaten feed are treated in the pond, some of the constituents can be released when water overflows from the pond or during draining. Too much excess feed can overwhelm natural processes in the pond and result in higher pollutant loads discharged.

There are a variety of practices that can be used to minimize wasted feed and optimize feed uptake by the aquatic animals. Facilities should use high-quality feed consistent with the nutritional needs of the cultured species to maximize feed consumption and conversion. The facility operator should know the feed requirements of the cultured species to accurately determine daily feed amounts. Facilities should use information including size of fish, water temperature, projected growth rates, and biomass in the system to determine appropriate feeding rates (Westers, 1995). Facilities should also store feed properly to maintain the nutrient quality and minimize humidity to prevent growth of molds or bacteria on feed.

In addition to the above practices, feed management practices for net pen facilities should monitor feeding rates using technologies such as underwater photography. Excess feed is the primary source of sediment accumulation beneath net pens, which can have an adverse effect on the benthic community.

Applicable production systems: ponds, flow-through, recirculating, net pens, and alligators.

7.2.2 Best Management Practices Plan

The best management practices plan includes components designed to minimize potential problems associated with aquatic animal pathogens, the escapes of nonnative species, and the use of drugs and chemicals. The goal of the BMP plan is to control conventional and nutrient pollutants in the discharge and to minimize the use of drugs and chemicals through BMPs.

An individual facility operator can develop a BMP plan tailored to the unique conditions of the CAAP facility, which will further reduce the discharge of pollutants consistent with the goals of the Clean Water Act. EPA called this plan the Pollutant Analysis at Critical Control Points (PACCP), which uses the well-established Hazard Analysis and Critical Control Points (HACCP) methodology developed by the U.S. Department of Agriculture (USDA) and the Food and Drug Administration (FDA) to ensure safe processing and importation of fish and shellfish products. Similar to the application of HACCP in food processing, PACCP can be used to identify and minimize important pollutants in effluents from CAAP facilities.

The HACCP methodology is a preventive system of hazard control rather than a reactive one (Gunderson and Kinnunen, 2001). For example, the overall goal of HACCP in seafood processing is to provide healthy, uncontaminated fish products to consumers (Gunderson and Kinnunen, 2001). CAAP facilities can use the similar PACCP approach to reduce or minimize the risks associated with pollutants in effluents, which should minimize impacts on receiving waters. The goals of PACCP are to identify the potential pollutants found in effluents from CAAP facilities (analogous to hazards in HACCP), to establish controls to minimize the pollutants, and to monitor the controls. The controls may be BMPs, such as feed management, or technologies, such as settling basins.

Seven basic principles of HACCP (Gunderson and Kinnunen, 2001) can be adopted for use in PACCP:

- Conduct a hazard analysis. Prepare a list of steps in the process where significant hazards occur and describe preventive measures.
- Identify the critical control points in the process.
- Establish controls for each critical control point identified.
- Establish critical control point monitoring requirements. Establish procedures for using monitoring results to adjust the process and maintain control.
- Establish corrective actions to be taken when monitoring indicates that there is a deviation from an established critical limit.
- Establish procedures to verify that the PACCP system is working correctly.
- Establish effective record-keeping procedures that document the PACCP system.

The PACCP approach considered for CAAP facilities could be used to minimize the discharge of pollutants commonly associated with CAAP facilities, including suspended solids, nutrients (nitrogen and phosphorus), and oxygen-demanding substances. In addition, PACCP could also be used to prevent escapement, and to evaluate and control pollutants such as therapeutic drugs and chemicals, pesticides, and pathogens. The most important aspect of using a management approach such as PACCP is the flexibility it provides both the facility operator and the regulator. More specifically, the facility operator has flexibility to develop a plan that fits the pollutant reduction needs of the individual facility. In addition, the operator can also use several different approaches to meet the goals of the plan, which in turn would have met the goals of the effluent limitations guidelines.

Applicable production systems: ponds, flow-through, recirculating, net pens, and alligators.

7.2.3 Health Screening

During normal operations, health screening involves the periodic sampling of the cultured species, which are screened for diseases, parasites, and body weight. Health screening can be done periodically and involves using small seines, cast nets, or dip nets to collect a random sample. The samples are visually inspected for diseases and parasites, then weighed and returned to the culture system.

Health screening allows for the early detection of certain diseases and parasites, such as columnaris or trichodina, which would otherwise not be detected until the outbreak had spread through the cultured population. Most states have diagnostic services available to assist in screening aquatic animals and identifying potential problems. Measuring weight allows producers to evaluate general health, determine how well the crop is performing, and continually update feeding regimes so that the most efficient feed rates are used. Health screening can also reduce the use of medicated feeds by identifying diseases early in their development before catastrophic outbreaks occur.

Applicable production systems: ponds, flow-through, recirculating, and net pens.

7.2.4 Inventory Control

Inventory control refers to the ongoing management of the amount of aquatic animal biomass in a culture system. Accurate recording-keeping and regular sampling to determine the average size of cultured species are important tools for estimating the amount of biomass in the production system. Higher biomass requires higher feed inputs, which could potentially lower the water quality by adding nutrients and reducing levels of dissolved oxygen. Production systems with high biomasses are subject to reduced growth rates, lower feed conversion ratios, and increased pollutant loadings from metabolic wastes. Information collected as part of inventory control helps the facility to develop cost-effective feeding regimes to promote optimal water quality.

Applicable production systems: ponds, flow-through, recirculating, net pens, and alligators.

7.2.5 Mortality Removal

Mortality of the cultured species in small numbers is a common occurrence in CAAP systems. Many of the mortalities float to the surface of the culture water and can be collected by hand or with nets. Mortality removal requires at least daily inspection of each culture unit to check for the presence of mortalities. Changes in operations should not be required because most producers complete at least one daily inspection of all production operations.

The timely removal of mortalities helps to prevent the spread of some diseases. Quickly removing mortalities before they start to decompose also reduces the introduction of excess nutrients into the system. There are no known disadvantages to the timely removal of mortalities; however, when ponds have large numbers of mortalities, removal might be more costly and require seines and crews similar to those used during harvest.

Application production systems: ponds, flow-through, recirculating, and net pens.

7.2.6 Net Cleaning

The regular cleaning of production nets helps to ensure the constant flow of water through the production area of the net pens. As the nets sit in the culture area, marine organisms attach to and grow on the nets, reducing the area of the openings. This reduction in area reduces the water flow through the net pens and the amount of dissolved oxygen available. Lack of water exchange due to a reduced open net area also increases the buildup of metabolic waste in the system.

Applicable production systems: net pens.

7.2.7 Pond Discharge Management

The most significant determinant for effluent quality in pond systems appears to be frequency and duration of pond drainings. The longer the time interval between drainings, the lower the wastewater volume and pollutant loads being discharged.

Pond systems are characterized as systems with infrequent discharges of water that have been treated by natural processes in the pond. There are two types of discharge from ponds: unintentional discharges due to overflow events and intentional discharges related to production practices such as harvesting.

Intentional discharges vary in frequency with the type of pond, the species being produced, and operator preferences. Water may be intentionally discharged from ponds to facilitate harvests or to improve the quality of the water in the pond by flushing or exchanging the water with new water additions.

Discharge management applies practices to reduce the volume of water discharged and to improve the quality of water through in-pond processes. By managing the frequency of discharge and holding water between crops, natural processes in the pond can assimilate wastes in the system. Other practices and technologies, such as aeration and feed management, also enhance water quality in the system.

Reusing water for multiple crops reduces the effluent volume. Effluent volume also can be reduced by draining ponds only when necessary. When possible, facilities can construct ponds that do not have to be drained for harvest. Facilities may also harvest fish by seining without partially or completely draining the pond unless it is necessary to harvest in deep ponds, restock, or repair pond earthwork.

Facilities may also design new ponds with structures that allow the ponds to be drained near the surface instead of from the bottom to improve the quality of the water drained. (Water from the bottom of the pond has more solids.) If necessary, facilities may install a swivel-type drain that can take in water from the surface and be lowered to completely drain the pond.

When ponds must be drained completely, it is recommended that the final 20% to 25% of the pond volume be discharged into a settling basin or held for 2 to 3 days to minimize suspended solids and then discharged slowly.

Applicable production systems: ponds.

7.2.8 Rainwater Management

Ponds can be managed to capture and store precipitation and minimize the need for expensive pumped groundwater or surface water. By maintaining pond depths between 6 to 12 in. below the height of the overflow structure, about 160,000 to 325,000 gal of storage capacity per surface acre of pond is available to capture direct rainfall and runoff from the pond walls. When more water is stored, less water is released through overflows and smaller amounts of potential pollutants are released. Capturing rainfall and reducing the amount of overflow reduces the need for pumping additional water into a pond to compensate for water lost to evaporation and infiltration. The capture of rainfall also reduces the amount of pollutants released into the waterways by extending the natural treatment processes that take place in the pond. This practice of preventing overflow by capturing rainwater is a common practice in many sectors within pond operations such as the catfish and baitfish industry. An additional benefit of this practice is that less energy is required for operating the facility.

For watershed ponds in larger watersheds, excess flows can be diverted away from the ponds. Diversions can be designed to provide sufficient water for the management of the pond and crop of fish while diverting excess water away from the pond. With less water flowing through the ponds during large runoff events, the overflow volume is reduced (Boyd et al., 2000).

There are little, if any, costs for this practice. The cost of energy and pump maintenance will be saved if water is not pumped into ponds to maintain water levels. The cost of adding more capacity by extending the height of drain structures should include pond design evaluations, materials to modify the structure, and labor to perform the modifications.

Applicable production systems: ponds.

7.2.9 Siting

Siting is the preimplementation planning that should take place to ensure that a net pen system is located in an area of adequate flow. Net pens placed in areas without sufficient tidal flushing have an increased probability of sedimentation beneath the pens. Net pens should also be located in areas where they are protected from storm events and do not become a hazard to navigation.

Applicable production systems: net pens.

7.2.10 Secondary Containment (Escapement Control)

Secondary containment involves the use of a second set of containment netting around a net pen system. The secondary containment netting should be positioned to capture any fish that might escape the primary containment netting due to damage to the net pen system, which could occur because of a storm event or other structural failure.

Influent screening is also applicable to all systems using ambient water sources for culture water. Influent screening can prevent the escapement of the cultured animals into source water. Screening also ensures the removal of harmful biological pollutants (wild fish and insects) that can significantly reduce production through predation.

Many facilities also screen effluents to guard against the escapement of the cultured species into the receiving waters. Effluent screening may include the use of metal grates or screens with mesh sizes small enough to exclude the cultured species from the effluent stream or the use of disinfection techniques such as ozonation or UV disinfection to kill any of the cultured species before they are discharged to a receiving waterbody.

Applicable production systems: ponds, flow-through, recirculating, and net pens.

7.2.11 Solids Removal BMP Plan

A facility's solids removal BMP plan includes components designed to minimize the discharge of solids from the facility. The CAAP facility would provide written documentation of a solids removal BMP plan and keep necessary records to establish and implement the plan.

Evaluating and planning site-specific activities to control the release of solids from AAP facilities is a practice currently required in several EPA regions as part of individual and general NPDES permits (e.g., shrimp pond facilities in Texas, net pens in Maine, and flow-through facilities in Washington and Idaho). BMP plans in these permits require the facility operators to develop a management plan for handling removed solids and preventing excess feed from entering the system. The BMP plan also ensures planning for proper operation and maintenance of equipment, especially treatment control technologies.

Applicable production systems: ponds, flow-through, recirculating, net pens, and alligators.

7.2.12 Drug and Chemical BMP Plan

The purpose of the drug and chemical BMP plan is to document the proper use and storage of specific drugs and chemicals in the production facility (e.g., amount of the drugs and chemicals used, proper storage of chemicals, and proper identification of the disease or problem and selection of proper chemical). The plan would also address practices to minimize the accidental spillage or release of drugs and chemicals. The CAAP facility is expected to provide written documentation of a BMP plan and keep necessary records to establish and implement the plan. Again, this tool is intended to be flexible; individual facilities are able to comply with the regulations by designing plans that address the unique needs of their facilities.

Applicable systems: ponds, flow-through, recirculating, net pens, and alligators.

7.3 WASTEWATER TREATMENT TECHNOLOGIES

7.3.1 Aeration

Some discharges from ponds, especially those from bottom waters, might be low in dissolved oxygen or have sufficient biochemical oxygen demand (BOD) to be problematic in receiving waters. When dissolved oxygen is a problem, aeration of pond discharges can be used to increase dissolved oxygen levels and prevent receiving water problems. Discharges from ponds can be aerated by using mechanical or passive aeration devices before they are discharged into a receiving water body. For relatively shallow ponds that are easily mixed, aerating the pond to meet fish culture needs should be sufficient to prevent problematic discharges.

Mechanical aeration devices include paddlewheel aerators and other surface aerators that create surface agitation. Surface agitation increases the surface area available for oxygen transfer. For deeper ponds, aeration of the discharge as it leaves the pond might be more practical and efficient. Passive aeration systems use the energy generated by falling water to increase the air-water surface area. Passive aeration systems take many forms, including waterfalls, rotating brushes, and splash boards. Mechanical aeration devices used for effluent treatment should undergo the same inspection and maintenance procedures implemented for aeration devices used in production areas. Passive aeration devices should be inspected regularly to remove debris and ensure correct function of the device.

Mechanical aeration can be integrated at most pond production facilities because the facilities already own the necessary equipment to aerate the pond. Passive aeration systems require no energy inputs and have low maintenance inputs once they have been constructed. Passive aeration systems can also be used to convey discharges to the receiving water body, thus reducing the potential for erosion along earthen conveyance systems.

Facilities with multi-pass serial raceways use active or passive aeration systems to maintain adequate dissolved oxygen concentrations in the culture water. Those facilities with sufficient hydraulic head between raceways tend to use passive or gravity aeration systems to increase the air-water interface, which in turn increases the dissolved oxygen content of the culture water (Wheaton, 1977).

Facilities with insufficient head between raceways use mechanical aeration systems to increase dissolved oxygen in the culture water. Recirculating systems also use mechanical aeration systems. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems add oxygen to the culture water under pressure to increase the efficiency of oxygenation. Diffuser aerators inject air or pure oxygen below the culture waters surface in the form of bubbles. As the bubbles pass through the water column, oxygen is transferred across the air-water interface (Wheaton, 1977).

Disadvantages of mechanical aeration systems include the energy and labor resources required to operate and maintain the aeration devices. Mechanical aerators should be operated and sited carefully to minimize the generation of suspended solids in the effluent.

Applicable production systems: ponds, flow-through, and recirculating.

7.3.2 Biological Treatment

Biological treatment involves the use of microorganisms to remove dissolved nutrients from a discharge (Henry and Heinke, 1996). Organic and nitrogenous compounds in the discharge can serve as nutrients for rapid microbial growth under aerobic (with oxygen) or anaerobic (with little or no oxygen) conditions. Biological treatment systems can convert approximately one-third of the colloidal and dissolved organic matter to stable end products and convert the remaining two-thirds into microbial cells, which can be removed through gravity separation.

Biological treatment operations are contained in tanks, lagoons, or filter systems. Most biological treatment systems are aerobic, meaning that they require free oxygen to maintain the microbial biomass necessary for effective treatment. Oxygen is usually supplied through diffusers in the bottom of the containment structure. In addition to providing oxygen, the diffusers ensure mixing of the discharge in the containment structure. After treatment, the discharge usually flows to polishing treatment operations before being discharged. Excess biomass from the containment structure is drained from the containment structure or captured in a settling device after the treated discharge leaves the biological treatment unit.

Biological treatment systems must have a constant supply of nutrient-rich water to keep the microorganism growth at its maximum potential. Aerobic biological systems also require supplemental oxygen systems to supply oxygen to the treatment system. In addition, biological systems in northern climates must be insulated from extremely cold conditions to remain effective throughout the winter. Biological treatment systems provide for the rapid conversion and removal of organic and nitrogenous pollutants in a small treatment volume. Biological treatment units also help to remove both fine and coarse solids as the discharge is settled.

Disadvantages of biological treatment systems include the cost associated with the continuous operation of these systems. Biological treatment systems are most effective when operated 24 h/d and 365 d/yr. Systems that are not operated continuously have reduced efficiency because of changes in nutrient loads to the microbial biomass. Biological treatment systems also generate a consolidated waste stream consisting of excess microbial biomass, which must be properly disposed. Operation and maintenance costs vary with the process used.

Applicable production systems: recirculating.

7.3.3 Constructed Wetlands

Constructed wetland treatment systems consist of shallow pools constructed on non-wetland sites with water at depths of usually less than 2 ft (Metcalf and Eddy, 1991; USEPA, 1996). Constructed wetlands provide substrate for specific emergent vegetation types such as cattail, bulrush, and reeds.

Constructed wetlands are designed to treat discharges through physical, chemical, and biological processes. The vegetation causes the discharge to flow slowly in a more serpentine manner, increasing the likelihood of solids settling. The vegetation also aids in the absorption of potential pollutants through plant and bacterial uptake, and it increases the oxygen level in the discharge flowing through it. Constructed wetland treatment systems can be designed to provide several different benefits, including treatment of the discharge through biological and chemical processes, temporary storage of discharges, recharge of aquifers, and reduction in discharge volume to receiving water bodies.

Constructed wetland treatment systems are most commonly used to provide a polishing or finishing step for discharge treatment operations. Newly constructed systems often require significant replanting of vegetation and backfilling of erosion damage. Once the system is operating properly, it should be inspected regularly to remove dead or fallen vegetation, check for erosion and channelization, and monitor sedimentation levels. Periodic harvest and proper disposal of the vegetation can also increase nutrient removal.

Constructed wetlands that have collected large amounts of sediment should be refurbished to ensure proper removal efficiencies and protect against the resuspension of collected solids. The section of the constructed wetland being refurbished should be taken offline for a period long enough to allow the removal of solids and regrowth of emergent vegetation. Solids removed from the wetland should either be land applied at agronomic rates or disposed using other sludge disposal methods.

Constructed wetlands have varying success in CAAP operations. Wetlands require large areas for treatment of relatively small volumes of water; therefore, facilities with limited available land for expansion are not able to use constructed wetlands. In many parts of the United States, constructed wetlands have seasonal differences in pollutant removal efficiencies. For example, in colder climates, constructed wetlands might discharge some dissolved nutrients during the colder season and become a sink for these pollutants during warmer months.

Applicable production systems: ponds, flow-through, and recirculating.

7.3.4 Injection Wells

Deep well injection is a wastewater disposal method by which wastewater is injected into a geologic layer beneath the earth's surface. EPA categorizes injection wells into five classes, based on the type of well and the waste disposed of. Class I and Class V wells are the only wells that may be used by CAAP facilities. Because of the costs associated with drilling and maintaining Class I wells, EPA assumes that most injection wells used by the CAAP industry are Class V wells. Class V injection wells are defined as shallow wells such as septic systems and drywells used to place nonhazardous fluids directly below the land surface (USEPA, 2002b). Class V wells include technologically advanced wastewater treatment systems and simple waste disposal systems, such as septic systems and cesspools. These wells are usually shallow and depend on gravity to "inject" wastes below the earth's surface. Because Class V wells may be hydraulically connected to drinking water aquifers, they should be closely monitored to avoid contamination (USEPA, 2002a).

Class I injection wells are defined as municipal or industrial injection wells that inject wastewater below the lower most underground source of drinking water (USWD). To qualify as a USWD, the aquifer or part of it must or be able to supply a public water system (PWS) or contain water with less than 10,000 mg/L of total dissolved solids, and not be exempted by EPA or state authorities from protection as a source of drinking water (USEPA, 2001).

Applicable production systems: ponds, flow-through, recirculating, and alligator.

7.3.5 Disinfection

Disinfection is a process by which disease-causing organisms are destroyed or rendered inactive. Most disinfection systems work in one of the following four ways: (1) damage to the cell wall, (2) alteration of the cell permeability, (3) alteration of the colloidal nature of the protoplasm, or (4) inhibition of enzyme activity (Henry and Heinke, 1996; Metcalf and Eddy, 1991).

Disinfection is often accomplished using bactericidal agents. The most common agents are chlorine, ozone (O_3), and ultraviolet (UV) radiation, or disinfection with UV light. Chlorination, the use of chlorine, is the most common method of disinfection used in the United States. Applications of high concentration of chlorine and ozone are used to disinfect the discharge stream. UV radiation disinfects by penetrating the cell wall of pathogens with UV light and completely destroying the cell or rendering it unable to reproduce.

Each disinfection system has specific operational factors related to its successful use, which might limit its effectiveness. Chlorine systems must have a chlorine contact time of 15 to 30 min, after which the discharge must be dechlorinated prior to discharge. Chlorine systems also run the risk of developing trihalomethanes, which are known carcinogens. Finally, the contact chamber must be cleaned on a regular schedule. Ozonation has limitations as well. This system requires the ozone to be generated on-site because its volatility does not allow it to be transported. On-site generation requires expensive equipment. UV radiation systems might have only limited value to dischargers without adequate TSS removal because the effectiveness of UV radiation systems decreases when solids in the discharge block the light. This system also requires expensive equipment with high maintenance costs to keep the system clean and replace UV bulbs.

Disinfection systems are beneficial because they render CAAP effluents free from active pathogenic organisms, regardless of their source. In addition, ozonation increases the dissolved oxygen content of the discharge stream and destroys certain organic compounds.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.6 Flocculation/Coagulation Tank

Flocculation or coagulation tanks are used to improve the treatability of wastewater and to remove grease and scum from wastewater (Metcalf and Eddy, 1991). The purpose of wastewater flocculation is to cluster fine matter to facilitate its removal. These clusters are often referred to as "flocs." The flocculation of wastewater by mechanical or air agitation increases the removal of suspended solids and BOD in primary settling facilities. For mechanical and air agitation, the energy input is commonly decreased so that the initially formed flocs will not be broken as they leave the flocculation facilities.

Disadvantages associated with flocculation/coagualtion tanks include high costs for maintenance and energy use.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.7 Filters

A number of different filtration systems are available to treat CAAP effluents, including microscreen filters, multimedia filters, and sand filters. Filters are used to remove solids and associated pollutants from the wastewater stream. Because small- diameter solids and associated nutrients contained in AAP industry effluents might be difficult to remove using only conventional (gravity) solids settling wastewater treatment operations, the use of filtration systems can efficiently increase the removal of these solids.

7.3.7.1 Microscreen Filters

Microscreen filters are commonly used filtration systems that consist of a synthetic screen of specific pore size that is used to remove solids from the effluent stream. Typical pore sizes for microscreen filters vary from 60 to 100 microns. Most microscreen filters operate by pumping the wastewater stream across the filter. Water passes through the screen and the solids are trapped on the surface of the screen, where they can later be flushed off to a solids holding unit for further treatment.

Applicable production systems: flow-through recirculating, and alligator.

7.3.7.2 Multimedia Filters

Multimedia filters are pressurized or non-pressurized treatment units that contain filter media of at least two different sizes. Wastewater flow is directed through a series of media (e.g., gravel and sand) using the coarser media first to facilitate the removal of larger solids, then media that are progressively less porous. At normal intervals the flow of wastewater is stopped and the filters are backwashed (cleaned) by forcing clean water through the filter in the direction opposite the wastewater flow. The procedure removes the collected solids from the filter media and directs waste to either an additional treatment unit or to a solids holding structure.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.7.3 Sand Filters

Sand filters can be pressurized or nonpressurized treatment units that contain sand. Sand filters are typically shallow beds of sand (24 to 30 in.) with a surface distribution system and an underdrain system (Metcalf and Eddy, 1991). The effluent is applied to the surface of the sand bed and the treated liquid is collected in the underdrain system. Most sand filters are buried underground.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.8 Hydroponics

Hydroponics is a process in which fine solids and nutrients in discharges are removed through the culture of aquatic or terrestrial plants (Metcalf and Eddy, 1991; Van Gorder, 2001). After a concentrated waste has been screened for coarse solids, it is diverted through the hydroponics system. A hydroponics system functions by suspending the root system of a plant species in the discharge stream to allow for the uptake of nutrients and removal of fine solids. After the plant species reaches its maximum growth, it is harvested and replaced with new plants that will more effectively absorb nutrients.

Operational factors associated with hydroponic systems include the need for a constant supply of a nutrient-rich discharge to the hydroponics operation for the cultured plants, the harvesting of the cultured aquatic plants, and disposal of any unused biomass. Constant nutrient-rich discharge requirements make hydroponic systems most applicable to recirculating and flow-through production systems. The constant harvesting or removal of biomass requires the dedication of labor resources to these tasks. Hydroponic systems that use aquatic plants, such as water hyacinth, duckweed, or pennywort, to treat discharges must develop composting plans because the biomass generated by these species has no commercial value.

Limitations of hydroponic systems for intensive CAAP systems include the size of the hydroponics system needed to effectively treat the discharge stream and climatic conditions. A small intensive CAAP operation can provide sufficient nutrients for a large-scale hydroponics operation; however, a large hydroponic treatment in northern climates is limited by the infrastructure inputs needed to operate the system year-round. Most hydroponically grown plants cannot effectively grow year-round without being located inside a greenhouse. Also, it can be very difficult to control the nutrient content of effluents to meet the specific nutrient needs of the cultured plants.

Advantages of hydroponic systems include the removal of nutrients, such as phosphorus and ammonia, and economic benefits through the sale of crops such as lettuce.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.9 Infiltration/Percolation Pond

Infiltration/percolation ponds allow for the simultaneous treatment and disposal of discharges by allowing them to gradually infiltrate the soils surrounding the basin. These ponds are constructed in soils with high hydraulic conductivity, allowing for the rapid infiltration of the wastewater into the soil (USEPA, 1996). Infiltration/percolation basins are designed with flat bottoms and without drainage structures. Evaporation is not considered to significantly increase the effectiveness of these basins.

Infiltration/percolation systems have few operational factors once they have been constructed. Before the ponds are constructed, soil tests must be conducted to ensure that the soils will have sufficient infiltration rates. Once operational, the basins should be inspected monthly to monitor water levels, check for soils accumulation, and determine whether any erosion of the banks has occurred. In some cases, it might be necessary to remove sediment and debris, and to till the basin bottom to preserve functionality.

All solids removed as part of an operation and maintenance program or in conjunction with a refurbishing effort should be treated in the same manner as solids from primary settling operations. The solids can be either be land applied at agronomic rates or disposed using other sludge disposal methods.

The primary advantage of these systems is the low operation and maintenance costs associated with their operation. Very few equipment or labor inputs are required after the construction of the systems; periodic brief inspection of the basin should be the only required operational task. Additional benefits of infiltration/percolation basins include the recharge of groundwater aquifers located below the basins and the absence of a discharge to a receiving water body.

Disadvantages of these systems include space availability for the basin and requirements for specific soil types with high hydraulic conductivities. Infiltration systems require a large surface area to successfully treat and dispose of large volumes of discharge. Another limitation of these systems is their long-term viability. Studies have shown the functional life of these systems is 5 to 10 yr.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.10 Oxidation Lagoons (Primary and Secondary)

Oxidation lagoons, also know as stabilization ponds, are usually earthen, relatively shallow wastewater treatment units used for the separation of solids and treatment of soluble organic wastes (Metcalf and Eddy, 1991). The basins are cleaned of solids as needed, which may be as long as once every 20 yr. Oxidation ponds are used extensively in the wastewater treatment industry and are commonly used by the alligator industry for the treatment of wastewater generated during pen cleaning.

Oxidation lagoons are usually classified as aerobic, anaerobic, or aerobic-anaerobic (facultative) according to the nature of the biological activity in the pond. Aerobic and facultative lagoons require that oxygen be added to all or parts of the lagoon constantly; therefore, in order to reduce costs, most lagoons in the alligator industry are operated as anaerobic lagoons.

The primary advantages of oxidation lagoons for treatment of alligator industry wastewater are the relative low costs of designing, constructing, and operating oxidation lagoons; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. Oxidation lagoons can also be operated without a discharge to surface waters through land application by spray irrigating water from the lagoon to prevent overflows.

Disadvantages of oxidation lagoons include the need to clean out accumulated solids; the potential odor emitted from the lagoon under normal operating conditions and during solids removal; and the inability of the lagoons to remove small-sized particles. The lagoon is designed to hold a fixed volume of solids and must be cleaned when the solids volume exceeds the design volume. Accumulated solids must be removed and properly disposed of through land application or other sludge disposal methods. Odors are a constant nuisance, and several methods are available to treat particularly bad odor problems. These solutions, however, tend to be costly and require additional equipment and operational resources.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.11 Quiescent Zones

Quiescent zones are used in raceway flow-through systems where the last approximately 10% of the raceway serves as a settling area for solids. It is important to note that flow-through system raceways are typically sized according to loading densities (e.g., 3 to 5 lb of fish per cubic foot), but the flow rate of water through the system drives the production levels in a particular raceway. Thus, EPA evaluated the impacts of placing quiescent zones in the lower 10% of raceways and found no adverse impacts on the production capacity of a facility (Hochheimer and Westers, 2002). The goal of quiescent zones and other in-system solids collection practices is to reduce the total suspended solids (and associated pollutants) in the effluent. Quiescent zone pollutant reductions were based on information supplied by industry representatives (Hinshaw, 2002, personal communication; Tetra Tech, 2002).

Quiescent zones usually are constructed with a wire mesh screen that extends from the bottom of the raceway to above the maximum water height to prohibit the cultured species from entering the quiescent zone. The reduction in the turbulence usually caused by the swimming action of the cultured species allows the solids to settle in the quiescent zone. Then, the collected solids are available to be efficiently removed from the system. The quiescent zones are usually cleaned on a regular schedule, typically once per week in medium to large systems (Tetra Tech, 2002), to remove the settled solids. The Idaho BMP manual (IDEQ, n.d.) recommends minimal quiescent zone cleaning of once per month in upper raceways and twice per month in lower units. The settled solids must be removed regularly to prevent breakdown of particles and leaching of pollutants such as nutrients and BOD.

Quiescent zones placed at the bottom or end of each raising unit or raceway allow for the settling of pollutants, mainly solids, before the pollutants are discharged to other production units (when water is serially reused in several raising units) or receiving waters.

Quiescent zones increase labor inputs because of the regular removal of collected solids and maintenance of screens that exclude the culture species. Cleaning of the quiescent zones also creates a highly concentrated waste stream that should be treated before it is discharged into a receiving water body.

Applicable production systems: flow-through.

7.3.12 Sedimentation Basins

Sedimentation basins, also known as settling basins, settling ponds, sedimentation ponds, and sedimentation lagoons, separate solids from water using gravity settling of the heavier solid particles (Metcalf and Eddy, 1991). In the simplest form of sedimentation, particles that are heavier than water settle to the bottom of a tank or basin. Facilities with high levels of production and feeding rates clean as often as once per month. Facilities with lower feeding rates clean less often, but at a minimum of once per year. Sedimentation basins are used extensively in the wastewater treatment industry and are commonly found in many flow-through aquatic animal production facilities. Most sedimentation basins are used to produce a clarified effluent (for solids removal), but some sedimentation basins remove water from solids to produce a more concentrated sludge. Both of these practices are used and are important in CAAP systems.

Settling in sedimentation basins occurs when the horizontal velocity of a particle entering the basin is less than the vertical (settling) velocity in the tank. To design a sedimentation basin, settling properties of an effluent are determined, particularly the settling velocities, and the basins are sized to accommodate the expected flow through the basin. The length of the sedimentation basin and the detention time can be calculated so that particles with a particular settling velocity (V_c) will settle to the bottom of the basin (Metcalf and Eddy, 1991). The relationship of the settling velocity to the detention time and basin depth is

$$V_c = \text{depth/detention time}$$

Other design factors include the effects of inlet and outlet turbulence, short-circuiting of flows within the basin, solids accumulation in the basin, and velocity gradients caused by disturbances in the basin (such as those from solids removal equipment).

Proper design, construction, and operation of the sedimentation basin are essential for the efficient removal of solids. Solids must be removed at proper intervals to ensure the designed removal efficiencies of the sedimentation basin.

The primary advantages of sedimentation basins for removing suspended solids from effluents from aquatic animal production systems are the relative low cost of designing, constructing, and operating sedimentation basins; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. In many CAAP systems, most of the solids from feces and uneaten feed are of sufficient size to settle efficiently in most moderately sized sedimentation basins. Many of the pollutants from CAAP operations can be partly or wholly removed with the solids captured in a sedimentation basin.

Disadvantages of a sedimentation basin include the need to clean out accumulated solids, the potential odor emitted from the basin under normal operating conditions, the odor produced by solids removed from the basin, and the inability of the basin to remove small-sized particles. Accumulated solids must be periodically removed and properly disposed of through land application or other sludge disposal methods. Odors are a constant nuisance, and several methods are available to treat particularly bad odor problems. These solutions, however, tend to be costly and require additional equipment and operational resources. System operators should attempt to minimize the breakdown of particles (into smaller sizes) to maintain or increase the efficiency of sedimentation basins. Many existing CAAP systems might have limited available space for the installation of properly sized sedimentation basins.

Sedimentation basins do not function well in colder climates, where they are likely to freeze. The viscosity of water increases as its temperature decreases which results in a decrease of the settling velocity of solids in the wastewater stream. Sedimentation basins designed for colder climates should include a safety factor to account for the longer detention times and inlet and outlet pipes should be located underwater to reduce the likelihood of freezing (Metcalf and Eddy, 1991).

Applicable production systems: ponds, flow-through, recirculating, and alligator.

7.3.13 Vegetated Ditches

A vegetated ditch is an excavated ditch that serves as a discharge conveyance, treatment, and storage system (USEPA, 1996). The vegetation layer aids in treating the discharge and reduces the susceptibility of the ditch banks and bottom to erosion. The length and width of the ditch are designed to allow for the slowing and temporary storage of the discharge as it flows toward the receiving water body. The walls of the ditch are excavated at an angle that supports the growth of a dense vegetation layer to enhance sedimentation and ensure against erosion.

Vegetated ditches are effective for treating wastewater discharges from CAAP facilities. They reduce the velocity of discharged water, which induces the settling of solids and associated pollutants by gravity. The vegetation ditch essentially traps pollutants such as suspended solids, settleable solids, and BOD and prevents them from being discharged into receiving waters. Depending on the porosity of the soil, a vegetated ditch might also allow wastewater to infiltrate the underlying soil as it flows along the channel.

Few operational factors are associated with using vegetated ditches. The main component of effective operation is proper design and construction of the ditch to ensure adequate vegetation and prevent scouring flows. Infiltration/percolation rates are a function of soil porosity and increase if the ditch is constructed in an area of high soil porosity. Vegetated ditches need to be maintained periodically to remove accumulated sediment for proper disposal and to maintain vegetation. Periodic harvest and proper disposal of the vegetation can also increase nutrient removal.

Disadvantages of vegetated ditches include lack of control over the treatment of the discharge. Furthermore, vegetated ditches have no backup system in the event of extremely high flow or during times when the vegetation needs to be reestablished.

Applicable production systems: ponds, flow-through, recirculating, and alligator.

7.3.14 Manure Treatment, Storage, and Disposal

7.3.14.1 Dewatering

Dewatering is the physical process used to reduce the moisture content of sludge to make it easier to handle for transport, or prior to composting or incineration of the sludge. Several techniques are used to dewater sludge; some rely on natural evaporation, whereas others use mechanically assisted physical means such as filtration, squeezing, capillary action, vacuum withdrawal, and centrifugal separation (Metcalf and Eddy, 1991).

Applicable production systems: flow-through, recirculating, and alligator.

7.3.14.2 Composting

Composting is a process by which organic material undergoes biological degradation to a stable end product (Metcalf and Eddy, 1991). Approximately 20% to 30% of the volatile solids are converted to carbon dioxide and water. As the organic material in the sludge decomposes, the compost heats to temperatures in the range of 120 to 160 ºF, and pathogenic organisms are destroyed.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.14.3 Land Application

Land application is the most common sludge disposal method in the CAAP industry (Chen et al., 2002). Land application of sludge is defined as the spreading of sludge on or just below the soil surface (Metcalf and Eddy, 1991). Application methods include using sprinklers and tank trucks to apply the sludge directly to the land. Sludge may be applied to agricultural land, forested land, disturbed land, and dedicated land disposal sites. In all of these cases, the land application is designed with the objective of providing further sludge treatment (Metcalf and Eddy, 1991). Sunlight, soil microorganisms, and dryness combine to destroy pathogens and other toxic organic substances present in sludge.

Applicable production systems: ponds, flow-through, recirculating, and alligator.

7.3.14.4 Publicly Owned Treatment Works (POTWs)

Publicly owned treatment works (POTWs) are wastewater treatment plants that are constructed and owned by a municipal government for the purpose of treating municipal and industrial wastewater from homes and businesses within its borders and/or surrounding areas. A facility that discharges to a POTW is considered to be an “indirect” discharger because the facility’s wastewater is directed to a POTW for treatment before being discharged to surface water. Some CAAP facilities are indirect discharges.

Applicable production systems: flow-through, recirculating, and alligator.

7.2.14.5 Storage Tanks and Lagoons

Manure, or sludge, from CAAP facilities has to be properly treated and disposed of. Storage tanks or storage lagoons are used to store untreated wastewater until the water can be treated or to store treated wastewater until it can be reused by the production system. Holding tanks, storage tanks, and surge tanks are used throughout the CAAP industry to hold untreated or treated wastewater.

Applicable production systems: flow-through, recirculating, and alligator.

7.3.15 Treatment Technologies Observed at EPA Site Visits

Table 7.2-1 describes the treatment technologies observed at the CAAP facilities that EPA visited as part of their data collection efforts.

Table 7.2-1. Aquatic Animal Production Site Visit Summary

State	*Species*	*Production System*	*Treatment Technologies*
MS	Catfish	Ponds	In-pond treatment
MS	Catfish	Ponds	In-pond treatment
MS	Catfish	Ponds	In-pond treatment
LA	Tilapia	Recirculating system	Land application of solids
LA	Alligators	Other – alligator huts	2-stage lagoon
LA	Hybrid striped bass	Ponds	In-pond treatment
LA	Crawfish	Ponds	In-pond treatment
LA	Crawfish	Ponds	In-pond treatment
LA	Crawfish	Ponds	In-pond treatment
PA	Trout	Flow-through	OLSB
PA	Trout	Flow-through	Full flow settling
NC	Trout	Flow-through	Quiescent zones with OLSB
NC	Trout	Flow-through	Quiescent zones with OLSB
NC	Tilapia	Recirculating system	Solids particle trap
NC	Hybrid striped bass, crawfish	Ponds	In-pond treatment
NC	Crawfish	Ponds	In-pond treatment
NC	Yellow perch, crab shedding, catfish	Ponds, tanks	Settling pond
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Flow-through	Quiescent zones with OLSB

State	Species	Production System	Treatment Technologies
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Ponds, flow-through	Quiescent zones with OLSB
WA	Salmon	Net pens	Feed management
WA	Salmon	Net pens	Feed management
WA	Salmon	Net pens	Feed management
WA	Molluscan shellfish - oysters	Flow-through, bottom culture	None
VA	Tilapia, hybrid striped bass, yellow perch	Recirculating system	Indirect discharger to POTW
MA	Hybrid striped bass	Recirculating system	Primary settling, biological treatment, microscreen, ozonation, indirect discharge
ME	Salmon, mussels	Net pens, off-bottom hanging culture (mussels)	Feed management, active feed monitoring
ME	Lobster	Other - pounds	None
ME	Salmon	Net pens	Feed management, active feed monitoring
HI	Ornamentals, seaweed	Flow-through	Infiltration ditches
HI	Tilapia, Chinese catfish	Net pen in pond	In-pond treatment
HI	Ornamentals	Flow-through	In-pond treatment
HI	Shrimp	Flow-through	In-pond treatment
HI	Shrimp, ornamentals, mullett, milkfish, red snapper	Flow-through	Infiltration ditches
HI	shrimp	Flow-through	Settling ponds
FL	Ornamentals	Ponds	Infiltration ditches
FL	Ornamentals	Ponds	Infiltration ditches
FL	Ornamentals	Ponds, recirculating systems	Infiltration ditches
FL	Ornamentals	Ponds	Infiltration ditches
FL	Ornamentals	Flow-through tanks, low flow rate	Infiltration ditches
FL	Ornamentals	Recirculating, flow-through tanks w/ low flow rate	Infiltration ditches
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control, drainage to natural wetland
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control
AL	Catfish	Ponds	Water management, erosion control, proper ditch construction

State	***Species***	***Production System***	***Treatment Technologies***
AL	Catfish	Ponds	Storage of runoff in reservoir, water management, erosion control, proper ditch construction
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control, stairstep watershed ponds
ME	Salmon - native endangered species	Flow-through	Settling ponds
ME	Salmon - native endangered species	Flow-through	Settling ponds
ME	Salmon	Flow-through	Settling ponds
ME	Brook trout, landlocked salmon (coho, chinook)	Flow-through	Settling ponds
ME	Brook trout, lake trout, splake	Flow-through	Settling pond
MI	Rainbow trout, brown trout	Flow-through	OLSB, quiescent zone, polishing pond
MI	Landlocked salmon	Flow-through	OLSB, quiescent zone, polishing pond
WI	Rainbow trout	Flow-through, earthen raceways	Riprap, erosion control, settling ponds, in pond settling
WI	Baitfish, various species of sport fish	Ponds	Erosion control, water management, discharge control (bottom drawing)
MO	Various warmwater species (including bluegill, catfish, paddlefish)	Ponds	Erosion control, water management, riprap
MN	Tilapia	Recirculating system	Lagoon, indirect discharge, composting
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent,
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent, constructed wetland
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent, constructed wetland
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control

State	Species	Production System	Treatment Technologies
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
MD	Multiple	Recirculating system	Sand filters

Note: OLSB = Offline settling basin.

7.4 REFERENCES

Boyd, C.E., J. Queiroz, J.-Y. Lee, M. Rowan, G. Whitis, and A. Gross. 2000. Environmental Assessment of Channel Catfish (*Ictalurus punctatus*) Farming in Alabama. *Journal of the World Aquaculture Society* 31:511-544.

Chen, S., S. Summerfelt, T. Losordo and R. Malone. 2002. Recirculating Systems, Effluents, and Treatments. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 119-140. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Gunderson J.L., and R.E. Kinnunen, ed. 2001. *Aquatic Nuisance Species-Hazard Analysis and Critical Control Point Training Curriculum* (ANS-HACCP). Minnesota Sea Grant Publication No. MN SG-F11. Duluth, MN.

Henry, J.G., and G.W. Heinke. 1996. *Environmental Science and Engineering*. 2d ed., pp. 445–447. Prentice-Hall, Inc., Upper Saddle River, NJ.

Hinshaw, J. 2002. North Carolina State University. Personal communication, February 20, 2002.

Hochheimer, J. and H. Westers. 2002. Technical Memorandum: Flow-Through Systems. Tetra Tech, Inc., Fairfax, VA.

IDEQ (Idaho Department of Environmental Quality). n.d. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

Metcalf and Eddy, Inc. 1991a. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 992-1002. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991b. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 351-352. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991c. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 741-745. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991d. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 248-271. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991e. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 1002-1011. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991f. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 604-614. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991g. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 220-240. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991h. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 855-877. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991i. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 842-850. McGraw Hill, Inc., NY.

Metcalf and Eddy, Inc. 1991j. *Wastewater Engineering: Treatment and Disposal*, 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 903-914. McGraw Hill, Inc., NY.

Tetra Tech, Inc. 2002, August. Site visit report for Clear Springs Foods, Inc., Box Canyon Facility, Buhl, ID.

USEPA (U.S. Environmental Protection Agency). 1996. *Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices*. EPA 843-B-96-001 U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2001. *Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells*. EPA 816-R-01-007. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002a. *Classes of Injection Wells*. <http://www.epa.gov/ogwdw000/uic/classes.html>. Accessed July 2002.

USEPA (U.S. Environmental Protection Agency). 2002b. *Final Determination Fact Sheet*. EPA 816-F-02-010. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Van Gorder, S.D. 2001. Wastewater Management in Closed Aquaculture Systems. Presented at the Aquaculture Waste Symposium, Roanoke, VA.

Westers, H. 1995. Feed and Feeding Strategies to Reduce Aquaculture Waste. Aquaculture Bioengineering Corporation, Aquaculture Engineering and Waste Management: In *Proceeding from the Aquaculture Expo VIII and Aquaculture in the Mid-Atlantic Conference*, pp. 365-376. Washington, DC, June 24-29, 1995.

Wheaton, F.W. 1977. *Aquacultural Engineering*. pp. 643-679. John Wiley and Sons, Inc., NY.

CHAPTER 8
LIMITATIONS AND STANDARDS: DATA SELECTION AND CALCULATION

This section describes the data sources, data selection, data conventions, and statistical methodology used by EPA in calculating the long-term averages, variability factors, and proposed limitations. The proposed effluent limitations and standards[1] are based on long-term average effluent values and variability factors that account for variation in treatment performance within a particular treatment technology over time. EPA is proposing limitations for flow-through and recirculating system subcategories. EPA is not proposing limitations for net pen systems. In calculating the proposed limitations for total suspended solids (TSS), EPA used a combination of the data from sampling episodes and data from industry discharge monitoring reports (DMRs). For both subcategories, EPA considered, but did not propose, limitations for total phosphorus. For the recirculating subcategory, EPA also considered, but did not propose, limitations for 5-day biochemical oxygen demand (BOD_5). This section describes the data selection and calculations for limitations based on the TSS, total phosphorus, and BOD_5 data.

Section 8.1 gives a brief overview of data sources (a more detailed discussion is provided in Chapter 3) and describes EPA's evaluation and selection of episode data sets that are the basis of the proposed limitations. Section 8.2 provides a more detailed discussion of the selection of the episode data sets for the options. Section 8.3 describes excluded and substituted data and Section 8.4 presents the procedures for data aggregation. Section 8.5 provides an overview of the limitations. Section 8.6 describes the procedures for estimation of long-term averages, variability factors, and limitations.

8.1 OVERVIEW OF DATA SELECTION

To develop the long-term averages, variability factors, and limitations, EPA used concentration data from facilities with components of the model technology in the two subcategories. These data were collected from two sources, EPA's sampling episodes and DMR data collected from EPA regional offices and in EPA's Permit Compliance System (PCS) database. This section refers to the DMR data as the facility's "self-monitoring episode."

EPA used only data from facilities that had the model technologies described in Chapter 9. EPA qualitatively reviewed these data from the sampling episodes and self-monitoring episodes and then selected episodes to represent each technology based on a

[1] In the remainder of this chapter, references to 'limitations' includes 'standards.'

review of the production processes and treatment technologies in place at each facility. Appendix C lists the data for the pollutants of concern (see Chapter 6) and Appendix D provides summary statistics for those data. The proposal record also contains an electronic spreadsheet of the data (DCN 50013, Section 10.1).

EPA's sampling episodes typically provided data for a range of pollutants. (See Chapters 3 and 6 for more information on sampling episode data.) In contrast, the industry self-monitoring (DMR) data were for only a limited subset of pollutants because most facilities monitor for only the pollutants specified in their permits.

EPA assumed that the DMR data were generated by the production method and treatment technologies reported by the facility in the Aquatic Animal Production (AAP) screener survey (USEPA, 2001) in response to the open-ended question (question 10) "What pollutant control practices do you use before water leaves your property?" Because of time constraints, EPA was able to incorporate additional DMR data from only four Virginia flow-through concentrated aquatic animal production (CAAP) facilities taken over a period of several years. For the final rule, EPA intends to review the PCS database and other possible sources of data to determine whether additional DMR data should be included in developing the final limitations.

Because of time constraints, in calculating the proposed limitations, EPA has not included self-monitoring data for any facility selected for an EPA sampling episode. For the final rule, if EPA selects data from a sampling episode, it is likely to use any self-monitoring data that were submitted by that facility or are available from PCS. In calculating the final limitations, EPA would then be likely to statistically analyze the data from each episode separately. This is consistent with EPA's practice for other industrial categories. Data from different sources generally characterize different time periods and/or different chemical analytical methods.

For the episode data sets that were used to develop the proposed limitations, EPA performed a detailed review of the data and all supporting documentation accompanying the data. This was done to ensure that the selected data represent a facility's normal operating conditions and ensure that the data accurately reflect the performance expected by the production method and treatment systems. Thus, EPA evaluated whether the data were collected while a facility was experiencing exceptional incidents (upsets). EPA also evaluated whether the DMR data were in compliance with the facility's permit.

The next section describes the episode and sample point selection for each subcategory and option.

8.2 EPISODE SELECTION FOR EACH SUBCATEGORY AND OPTION

This section describes the episodes selected for each technology option for the two proposed subcategories (flow-through and recirculating systems). Table 8.2-1 summarizes the episode and sample point selections. Appendix C lists the data for the pollutants of concern (see Chapter 6) and Appendix D provides summary statistics of those data.

Table 8.2-1. Summary of Episode and Sample Point Selection

Subcat	*Option*	*Episode*	*Influent* [a]	*Effluent* [a]
Flow-through	N/A[b]	6297C[c]	SP-12	SP-13(dup SP-14)
		6297D[d]	SP-4	N/A
		6297F[e]	N/A	SP-2 (dup SP-3)
	Raceway	6297E	N/A	SP-5 (dup SP-6)
		6460B	N/A	SP-7
	OLSB	6297A	SP-7	SP-8 (dup SP-9)
		6297B	SP-10	SP-11
		6460C	SP-8	SP-9
	1	6297G	SP-7	SP-8 (dup SP-9) and SP-5 (dup SP-6)
		6297H	SP-10	SP-11 with SP-5 (dup SP-6)
		6297I	SP-12	SP-13 (dup SP-14) and SP-2 (dup SP-3)
		6460A	N/A	SP-7 and SP-9
		DMR1	N/A	SP-1
		DMR3	N/A	SP-1
		DMR4	N/A	SP-1
	3	6460D	SP-7, SP-8	SP-10 (dup SP-11)
		DMR2	N/A	SP-1
Recirculating	N/A[b]	6439C[f]	SP-2	N/A
	1	6439A	SP-3	SP-4
	3	6439B	SP-8	SP-9 (dup SP-11)

[a]When EPA collected duplicate samples, it assigned a different sample point designation than the sample point for the original sample. The parentheses identify the sample points for the duplicates.
[b]Although these sample points were not considered in developing the limitations and are labeled as "Not applicable" (N/A), EPA used these data to review the overall performance at the facility. EPA has included these data in its data listings and summary statistics.
[c]Influent and effluent corresponding to the Hatch House OLSB.
[d]Source water.
[e]Effluent from the Hatch House.
[f]Overflow from production tanks.
Note: N/A, data were not provided for that location.

If a facility had multiple production and treatment trains that EPA sampled separately, EPA has treated the data as if they were collected from different facilities because the trains are operated independently with different waste streams. In the documentation, the episode identifier is appended with a character, such as "A", to indicate that the data are from one of the multiple trains. In the following sections and in the public record, EPA has masked the identity of the facilities for which it used DMR data. These episodes are identified only as DMRx where "x" is a one-digit number assigned to each DMR episode. EPA has arbitrarily assigned the sample point designation SP-1 to all DMR episodes.

8.2.1 Flow-through Subcategory

For the flow-through subcategory, EPA proposed limitations for Options 1 and 3. EPA also considered separate limitations for raceway and offline settling basins (OLSBs), although it chose to propose limitations for only the combined discharges. This section describes the data used to develop the limitations for Option 1, Option 3, raceways, and OLSBs. For this subcategory, EPA proposed limitations for TSS and considered limitations on total phosphorus discharges.

8.2.1.1 Option 1

In developing the proposed limitations for Option 1, EPA used data from two of its sampling episodes, 6297 and 6460, and three DMR episodes, DMR1, DMR3, and DMR4. As explained below, EPA used the data from the three DMR episodes and mathematically aggregated the data from each of the two episodes to obtain a total of seven process/treatment streams that it considered as seven episodes in its calculations. This section describes the data from each episode.

Episode 6297 was conducted on December 11-16, 2000, in Buhl, Idaho, at the Box Canyon trout facility owned and operated by Clear Springs Foods, Inc. Box Canyon is the largest trout-producing raceway system in the United States and has an average annual production of some 8 million pounds. The facility includes a hatchery consisting of upwelling incubators; 20 raceways and four steel tanks for producing fry; 180 flow-through raceways for growout; and three OLSBs for solids collection. An overall schematic of the facility with the sampling point locations is presented as Figure 8.2-1. Surface water from Box Canyon Spring is piped under the Snake River to Box Canyon at a rate of approximately 300 cubic feet per second (cfs). The water is diverted under the river through three steel pipes and through three turbines for electrical energy production. After passing through the turbines, the flow is split among the Blueheart, Eastman, and hatchery sections of the facility. Both the Blueheart and Eastman sections of the facility contain 90 concrete raceways holding approximately 10,000 fish per raceway. Automatic fish feeders are located above each raceway in four different locations. Automated feeding systems are used to feed the fish in the 180 raceways used for growout. All feeding in the hatchery is done by hand. Wastewater treatment operations at Box Canyon include quiescent zones, offline settling basins, and regular vacuuming of raceways. The quiescent zone at the terminal end of each raceway allows fecal material to settle before the raceway water is reused or discharged to the Snake River. Solids are removed from the quiescent zone by vacuuming. The vacuumed solids then flow by gravity to the designated OLSB for each section of the facility. In evaluating Option 1, EPA considered three process/treatment streams at this facility by mathematically combining the data from:

1. The Eastman raceway and its OLSB. This was labeled as *episode 6297G*.

2. The Eastman raceway and the Blueheart OLSB. This was labeled as *episode 6297H*.
3. The hatch house and its OLSB. This was labeled as *episode 6297I*.

EPA also received self-monitoring data from the Box Canyon facility and has summarized that information in *Listings for Episode 6297: DMR Data, Summary Statistics, and Estimates* (SAIC, 2002a). Because of time constraints, EPA did not include these data in developing the proposed limitations, but is considering their use for the final rule. In the record, EPA used the reported weekly flows to mathematically combine the data from different sample points. For the few cases where weekly flows were not reported, EPA used the average flow for the month. If a monthly average flow was also missing, then EPA used the maximum flow value reported for the month.

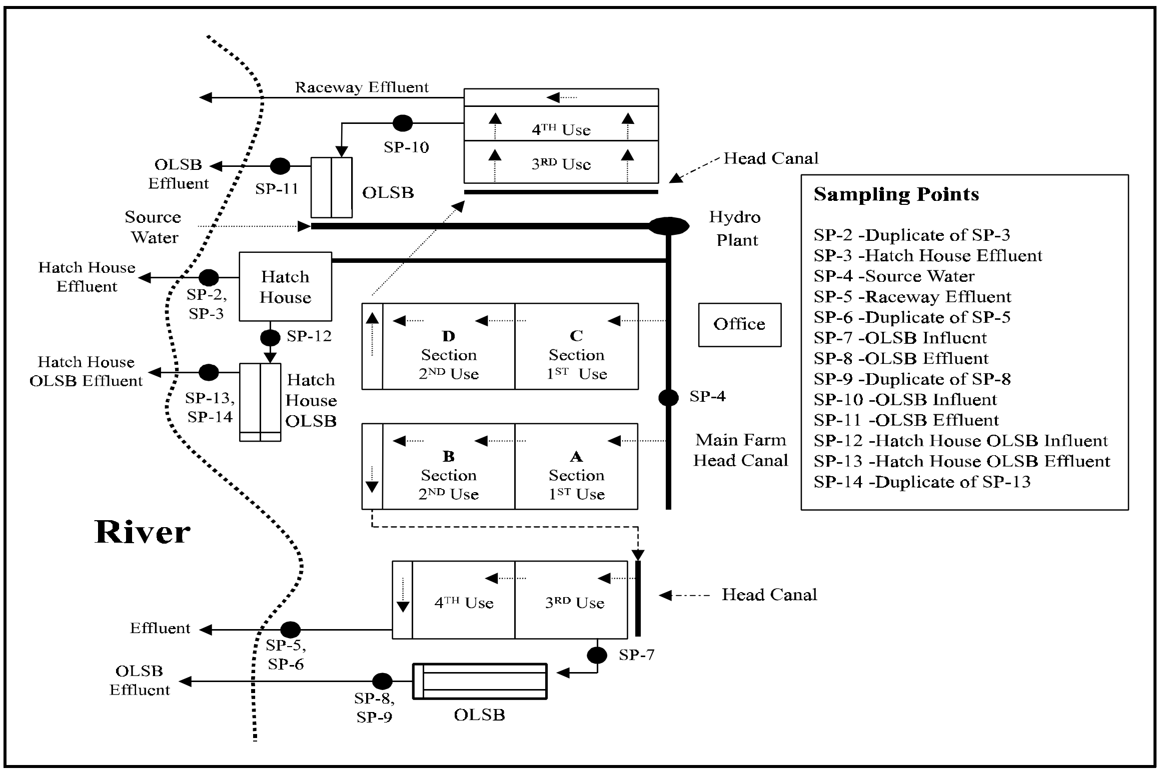


Figure 8.2-1. Schematic of Sampling Points and Facility for Episode 6297

Episode 6460 was conducted on August 24-29, 2001, in Harrietta, Michigan, at the Harrietta Hatchery trout facility. Harrietta Hatchery is a Michigan Department of Natural Resources hatchery whose mission is to produce rainbow and brown trout for stocking into Michigan waters. Harrietta produces about 1.2 million trout annually. The trout are harvested from Harrietta's raceways when they are about 5 to 8 in. in length or about eight to ten fish to the pound. Figure 8.2-2 shows the process diagram for the facility associated with this episode. Harrietta uses well water at a rate of up to 5.5 million gallons per day (mgd) from pumped and artesian wells that flow to the hatchery and 12 raceways. Wastewater treatment operations at the Harrietta Hatchery include the use of baffles, quiescent zones (sediment traps) in each raceway, a manure storage/settling pond, and a polishing pond. The outdoor growout system consists of 12 covered raceways grouped in three blocks of four. Water flows through each raceway in the block and is collected in a common trough, which is discharged either to an aeration shed or a polishing pond. At the downstream end of each raceway is a quiescent zone where solids settle and are easily vacuumed. The vacuumed solids are diverted into a manure collection/storage basin (or OLSB) adjacent to the polishing pond. A standpipe in each raceway can also be pulled to send water and solids to the OLSB. This OLSB has an intermittent discharge, typically weekly, and only occurred once during EPA's sampling episode (on 8/27/01). To accommodate EPA's schedule, the facility discharged from the OLSB two days earlier than originally scheduled. In evaluating Option 1, to obtain one value for the combined discharges for each day that EPA sampled, the Agency mathematically combined the data from the commingled raceway discharge and the OLSB discharge. Because the OLSB discharged on only 1 day, the daily values for the other 4 days are based on only the commingled raceway discharge. The daily data for this option were labeled as *episode 6460A*.

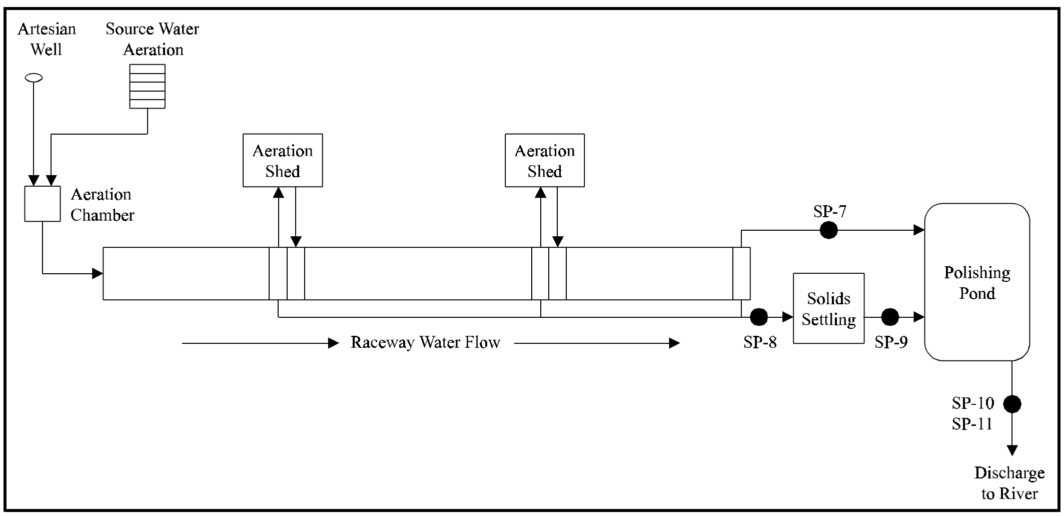


Figure 8.2-2. Schematic of Sampling Points and Facility for Episode 6460

For the three DMR episodes (DMR1, DMR3, and DMR4), EPA assumed that the discharges resulted from the combined flows from raceways and OLSBs based on examination of the facility NPDES permit and the responses to the open-ended question (question 10) in the AAP screener questionnaire, "What pollutant control practices do you use before water leaves your property?" The facility that provided the DMR1 data is Virginia Department of Game and Inland Fisheries, Coursey Springs Fish Culture Station, Millboro, Virginia, a state fish hatchery that produces brook, brown, and rainbow trout for stocking in public trout streams. The facility uses about 11.5 mgd of spring water and uses quiescent zones and full-flow settling for removing solids from the effluent stream. The DMR3 data are from Virginia Department of Game and Inland Fisheries, Marion Fish Culture Station, Marion, VA, another state facility that produces trout, muskellunge, pike, and walleye for stocking in public waters. This facility separately samples its effluents from quiescent zones and a full-flow settling basin below the trout raceways. The facility then mathematically combines the two effluent data values to obtain one daily value for the facility. The facility uses about 2.0 mgd for the trout production part of the operation. The DMR4 data are from Virginia Department of Game and Inland Fisheries, Buller Fish Culture Station, Marion, VA, a state-owned trout rearing station that produces trout for stocking in public waters. The facility samples its effluents from quiescent zones and a full-flow settling basin, separately, and then mathematically combines the results to obtain one daily value. The facility uses about 0.5 mgd for the trout production.

8.2.1.2 Option 3

For Option 3, EPA evaluated the data collected from the polishing pond at episode 6460 and the data from DMR2. Because the TSS data from DMR2 exceeded the monthly permit limit for 1 month, EPA excluded these data from further consideration in calculating the proposed TSS limitations. Thus, the proposed TSS limitations were based on the discharge from the polishing pond at episode 6460. The data were labeled as *episode 6460D*, and the facility is described under Option 1. The DMR2 data are from a state-owned trout production facility for stocking in public trout streams. The facility produces brook, brown, and rainbow trout in raceways. Effluents from the raceways flow into a two-stage settling pond for primary settling and secondary solids polishing. The system flow rate is about 2.8 mgd.

8.2.1.3 Raceways

To evaluate the performance of the raceways in Option 1, EPA calculated limitations using the data for the Eastman raceway from episode 6297 (labeled as *episode 6297E*) and the discharge (labeled as *episode 6460B*) from one of the blocks of raceways from episode 6460.

8.2.1.4 OLSBs

To evaluate the performance of the OLSBs in Option 1, EPA calculated limitations using the data for the Eastman and Blueheart OLSBs from episode 6297 (labeled as *episode 6297A* and *episode 6297B*, respectively) and the OLSB from episode 6460 (labeled as *episode 6460C*).

8.2.2 Recirculating Subcategory

For the recirculating subcategory, EPA proposed limitations for Option 3 based on the permit limits from the facility that EPA sampled during episode 6439, which was conducted at Fins Technology, LLC on April 23-28, 2001 in Turners Falls, Massachusetts. Fins Technology, started in 1990 as AquaFuture, Inc, produces about 1 million pounds of hybrid striped bass per year in a recirculating system. It sells live and iced whole fish throughout the U.S. east coast and New England. A unique feature of this facility is its ability to grow hybrid striped bass from egg to foodfish in recirculating systems, all of which are located on-site. Fins Technology uses recirculating system technology to maintain water quality in the growing tanks for the hybrid striped bass. The facility adds less than 10% of the total system volume each day to offset water losses because of filter backwashes and to account for some of the inefficiencies in the recirculating system. Wastewater is generated from solids filtration equipment that maintains process water quality in the recirculating system. Solids are generated when the solids filters are backwashed throughout the day. Additional system overflow water is added to the waste stream and comes directly from the process tanks. Because the facility has claimed its process diagram as CBI, EPA is providing only a brief summary of the process at that facility in Figure 8.2-3.

Rather than basing the proposed TSS limitations on the data it had collected, EPA used the permit limits for this facility because the facility had exceeded those limits during EPA's sampling episode. This facility is generally capable of complying with its permit limits, and therefore, EPA determined that the permit limits more accurately reflected normal operations of the model technology for this option. EPA also noted that the effluent from the polishing pond was more variable than EPA's experience with typical performance of polishing ponds. EPA is considering BOD and total phosphorus limitations for the recirculation subcategory in addition to TSS. The data and summary statistics for this episode are included in Appendices C and D. Table 8.6-2 in Section 8.6 provides the long-term average and variability factors for this episode.

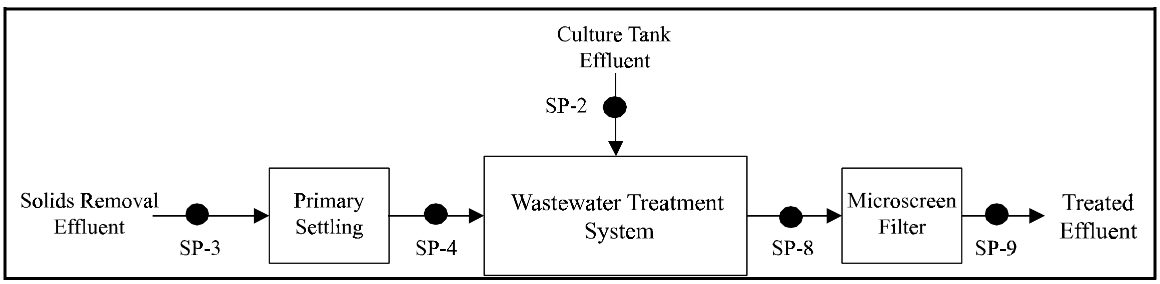


Figure 8.2-3. Schematic of Sampling Points and Facility for Episode 6439

8.3 DATA EXCLUSIONS AND SUBSTITUTIONS

In some cases, EPA did not use all of the data described in Section 8.2 in calculating the limitations. Other than the data exclusions and substitutions described in this section and those resulting from the data editing procedures, EPA has used the data from the episodes and sample points identified in Table 8.2-1.

EPA excluded the data for one sample (55949) of the influent during episode 6297 (sample point 12) because it was filtered before measuring the concentration levels. Instead, in its statistical analyses, EPA used the concentration data from another sample (55948) collected at approximately the same time at that sample point, but was not filtered prior to measuring the concentrations.

For the DMR data (episodes DMR1, DMR2, DMR3, and DMR4), EPA reviewed the NPDES permit information for each facility to determine the reporting requirements. For the parameters of interest to EPA (TSS, BOD, and settleable solids), the monitoring frequency was typically once per month or once per three months and the samples were typically 8-hour composite samples collected hourly or until 5 grab samples were collected. Other parameters sometimes required more frequent monitoring, which were reported over more than one 24-hour period. Since facilities report multiple parameters in a single report, multiple days are sometimes recorded as the monitoring period for all of the data. Based on the permit information, EPA assumed that each reported value (for the parameters of interest) was from a single 24-hour period. For purposes of the statistical analyses and data listings, EPA assumed that the sample date was the one associated with the "Monitoring from" date (starting date of the sampling) listed in the DMR.[2]

The DMR data did not indicate whether they were nondetected (ND) or noncensored (NC) values. Except for settleable solids, EPA assumed that all values were NC. For settleable solids, EPA assumed that all reported values of 0.1 mL/L were ND. For the two values reported at 0.01 mL/L, EPA assumed that they were ND and replaced the reported value with the detection limit of 0.1 mL/L. (One value is from DMR2 and the other from DMR4.) In the memorandum *Censoring Assumptions for DMR Data in the Aquatic Animals Proposal* (USEPA, 2002), EPA evaluates the effect of assuming that low values of TSS are ND rather than NC on the estimates.

In general, EPA used the reported measured value or sample-specific detection limit in its calculations. However, for hexane extractable material (HEM) and hexanoic acid, EPA compared each laboratory-reported sample result to the minimum level (ML) in the chemical analytical method. The ML is defined as the lowest level at which the entire analytical system must give a recognizable signal and an acceptable calibration point for the analyte. When an ML is published in a method, the Agency has demonstrated that at least one well-operated laboratory can achieve the ML, and when that laboratory or another laboratory uses that method, it is required to demonstrate, through calibration of the instrument or analytical system, that it can make measurements at the ML. HEM and hexanoic acid are the only two pollutants of concern measured using EPA Methods with the ML concept, so EPA determined that only their data needed to be compared in this manner. None of the measured values or sample-specific detection limits were reported with values below the ML. If EPA had found any such values (or if it finds such values for the final rule), EPA would have substituted the ML for these lower values. In its statistical models, EPA also would have assumed that these substitutions were ND concentrations.

8.4 DATA AGGREGATION

In some cases, EPA determined that two or more samples had to be mathematically aggregated to obtain a single value that could be used in other calculations. In some

[2] There was one exception for DMR4, which reported two settleable solids data with the same starting date of sampling and different ending dates. For the data point reported with a later ending date, EPA assumed that the data were taken the day after the reported starting date

cases, this meant that field duplicates and grab samples were aggregated for a single sample point. In addition, for one facility, data were aggregated to obtain a single daily value representing the facility's influent or effluent from multiple sample points. Appendix C lists the data after these aggregations were completed and a single daily value was obtained for each day for each pollutant. *Listing 5: Unaggregated Data for Pollutants of Concern* (SAIC, 2002b) provides the unaggregated data.

In all aggregation procedures, EPA considered the censoring type associated with the data, as well as the measured values to be detected. In statistical terms, the censoring type for such data was NC. Measurements reported as less than some sample-specific detection limit (e.g., <10 mg/L) were censored and were considered to be ND. In the tables and data listings in this document and the record for the rulemaking, EPA has used the abbreviations NC and ND to indicate the censoring types[3].

The distinction between the two censoring types is important because the procedure used to determine the variability factors considers censoring type explicitly. This estimation procedure modeled the facility data sets using the modified delta-lognormal distribution. In this distribution, data are modeled as a mixture of two distributions. Thus, EPA concluded that the distinctions between detected and nondetected measurements were important and should be an integral part of any data aggregation procedure. (See Appendix E for a detailed discussion of the modified delta-lognormal distribution.)

Because each aggregated data value was entered into the modified delta-lognormal model as a single value, the censoring type associated with that value was also important. In many cases, a single aggregated value was created from unaggregated data that were all either detected or nondetected. In the remaining cases with a mixture of detected and nondetected unaggregated values, EPA determined that the resulting aggregated value should be considered to be detected because the pollutant was measured at detectable levels.

This section describes each of the different aggregation procedures. They are presented in the order in which the aggregation was performed: filtrate samples, field duplicates, grab samples, and multiple sample points.

8.4.1 Aggregation of Filtrate Samples

For SP 12 at episode 6297, the laboratory filtered the samples and processed the aqueous filtrate and filtered solids separately. As a result, for the classical/conventional analytes and the metals pollutants, the laboratory reported two results for each sample. The aqueous filtrate results were reported in weight/volume units (e.g., mg/L), while the filtered solids were reported in weight/weight units (e.g., mg/kg). EPA aggregated the results as explained in the memorandum *Conversion of Aquaculture Data for Episode*

[3] Laboratories can also report numerical results for specific pollutants detected in the samples as "right-censored." Right-censored measurements are those that are reported as being greater than the highest calibration value of the analysis (e.g., >1000 µg/L). None of the data used to develop the proposed TSS limitations were right-censored.

6297 (DynCorp, 2002). *Listing of the Aquatic, Solid, and Combined Filtrate Data for Facility 6297*" (SAIC, 2002c) provides the reported (unaggregated) and aggregated values.

8.4.2 Aggregation of Field Duplicates

During the sampling episodes, EPA collected a small number, about 10%, of field duplicates. Field duplicates are two samples collected from the same sampling point at approximately the same time, assigned different sample numbers, and flagged as duplicates for a single sample point at a facility. *Listing 6: Individual Field Duplicate Sample Results for Pollutants of Concern* (SAIC, 2002d), provides the individual values for the field duplicates for the pollutants of concern for the sample points identified in Table 8.2-1.

Because the analytical data from each duplicate pair characterize the same conditions at the same time at a single sampling point, EPA aggregated the data to obtain one data value for those conditions by calculating the arithmetic average of the duplicate pair.

In most cases, both duplicates had the same censoring type. In these cases, the censoring type of the aggregate was the same as the duplicates. In the remaining cases, one duplicate was an NC value and the other duplicate was an ND value. In these cases, EPA determined that the appropriate censoring type of the aggregate was NC because the pollutant had been present in one sample. (Even if the other duplicate had a zero value,[4] the pollutant still would have been present if the samples had been physically combined.) Table 8.4-1 summarizes the procedure for aggregating the analytical results from the field duplicates. This aggregation step for the duplicate pairs was the first step in the aggregation procedures for both influent and effluent measurements.

Table 8.4-1. Aggregation of Field Duplicates

If the Field Duplicates Are:	*Censoring Type of Average is:*	*Value of Aggregate is:*	*Formulas for Aggregate Value of Duplicates:*
Both NC	NC	Arithmetic average of measured values	$(NC_1 + NC_2)/2$
Both ND	ND	Arithmetic average of sample-specific detection limits	$(DL_1 + DL_2)/2$
One NC and one ND	NC	Arithmetic average of measured value and sample-specific detection limit	(NC + DL)/2

NC - noncensored (or detected). ND - nondetected. DL - sample-specific detection limit.

[4] This is presented as a “worst-case” scenario. In practice, the laboratories cannot measure ‘zero’ values. Rather they report that the value is less than some level.

8.4.3 Aggregation of Grab Samples

During the sampling episodes, EPA collected mostly composite samples. However, the chemical analytical method specifies that grab samples must be used for two pollutants of concern: oil and grease (O&G) and settleable solids. For O&G, EPA collected multiple (usually three) grab samples during a sampling day at a sample point. For settleable solids, a single grab sample was collected each day at each sample point. To obtain one value characterizing the pollutant levels at the sample point on a single day, EPA mathematically aggregated the measurements from the grab samples. *Listing 7: Individual Grab Sample Results for Pollutants of Concern* (SAIC, 2002e), provides these values for the sample points identified in Table 8.2-1.

The procedure arithmetically averaged the measurements to obtain a single value for the day. When one or more measurements were NC, EPA determined that the appropriate censoring type of the aggregate was 'non-censored' because the pollutant was present. Table 8.4-2 summarizes this procedure.

8.4.4 Aggregation of Data Across Sample Points ("Flow-Weighting")

After field duplicates and grab samples were aggregated, the data from each sample point in facilities with multiple sample points were further aggregated to obtain a single daily value representing the episode's influent or effluent. *Listing 5: Unaggregated Data for Pollutants of Concern* (SAIC, 2002b) provides the unaggregated data for the pollutants of concern for the sample points identified in Table 8.2-1.

Table 8.4-2. Aggregation of Grab Samples

If the Grab or Multiple Samples are:	*Censoring Type of Daily Value is:*	*Daily Value is:*	*Formulas for Calculating Daily Value:*
All NC	NC	Arithmetic average of measured values	$\frac{\sum_{i=1}^{n} NC_i}{n}$
All ND	ND	Arithmetic average of sample-specific detection limits	$\frac{\sum_{i=1}^{n} DL_i}{n}$
Mixture of NC and ND values (total number of observations is n = k + m)	NC	Arithmetic average of measured values and sample-specific detection limits	$\frac{\sum_{i=1}^{k} NC_i + \sum_{i=1}^{m} DL_i}{n}$

NC - noncensored (or detected). ND - nondetected. DL - sample-specific detection limit.

In aggregating values across sample points, if one or more of the values were NC, the aggregated result was considered NC because the pollutant was present in at least one stream. When all of the values were ND, the aggregated result was considered to be ND. The procedure for aggregating data across streams is summarized in Table 8.4-3. The following example demonstrates the procedure for hypothetical pollutant X at an episode with discharges on Day 1 from an OLSB and raceway for Option 1 of the flow-through subcategory.

Example of calculating an aggregated flow-weighted value:

Day	Sample Point	Flow (cfs)	Concentration (mg/L)	Censoring
1	Raceway	1	50	NC
1	OLSB	100	10	ND

Calculation to obtain aggregated, flow-weighted value:

$$\frac{(100\ \text{cfs} \times 10\ \text{mg/L}) + (1\ \text{cfs} \times 50\ \text{mg/L})}{100\ \text{cfs} + 1\ \text{cfs}} = 10.4\ \text{mg/L}$$

Because one of the values was NC, the aggregated value of 10.4 mg/L is NC.

Table 8.4-3. Aggregation of Data Across Streams

If the n Observations are:	***Censoring Type is:***	***Formulas for Value of Aggregate***
All NC	NC	$\frac{\sum_{i=1}^{n} NC_i \times flow_i}{\sum_{i=1}^{n} flow_i}$
All ND	ND	$\frac{\sum_{i=1}^{n} DL_i \times flow_i}{\sum_{i=1}^{n} flow_i}$
Mixture of k NC and m ND (total number of observations is n=k+m)	NC	$\frac{\sum_{i=1}^{k} NC_i \times flow_i + \sum_{i=1}^{m} DL_i \times flow_i}{\sum_{i=1}^{n} flow_i}$

NC - noncensored (or detected). ND - nondetected. DL - sample-specific detection limit.

8.5 OVERVIEW OF LIMITATIONS

The preceding sections discuss the data selected as the basis for the limitations along with the data aggregation procedures EPA used to obtain daily values in its calculations. This section provides a general overview of limitations before returning to the development of the proposed limitations for the CAAP industry.

For the CAAP industry, the limitations for pollutants for each option are provided as daily maximums and maximums for monthly averages. Definitions provided in 40 CFR 122.2 state that the daily maximum limitation is the "highest allowable 'daily discharge,'" and the maximum for monthly average limitation (also referred to as the "average monthly discharge limitation") is the "highest allowable average of 'daily discharges' over a calendar month, calculated as the sum of all 'daily discharges' measured during a calendar month divided by the number of 'daily discharges' measured during that month." Daily discharges are defined as the "'discharge of a pollutant' measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling."

This section describes EPA's objective for daily maximum and monthly average limitations, the selection of percentiles for those limitations, and compliance with final limitations. EPA has included this discussion in Chapter 8 because these fundamental concepts are often the subject of comments on EPA's effluent guidelines regulations and in EPA's contacts and correspondence with industry.

8.5.1 Objective

In establishing daily maximum limitations, EPA's objective is to restrict the discharges on a daily basis at a level that is achievable for a facility that targets its treatment at the long-term average. EPA acknowledges that variability around the long-term average results from normal operations. Occasionally, facilities discharge at a level that is greater than or considerably lower than the long-term average. To allow for these possibly higher daily discharges, EPA has established the daily maximum limitation. A facility that consistently discharges at a level near the daily maximum limitation is *not* targeting its treatment to achieve the long-term average, which is part of EPA's objective in establishing the daily maximum limitations. That is, targeting treatment to achieve the limitations might result in frequent values exceeding the limitations due to routine variability in treated effluent.

In establishing monthly average limitations, EPA's objective is to provide an additional restriction to help ensure that facilities target their average discharges to achieve the long-term average. The monthly average limitation requires continuous dischargers to provide on-going control, on a monthly basis, that complements controls imposed by the daily maximum limitation. In order to meet the monthly average limitation, a facility must counterbalance a value near the daily maximum limitation with one or more values well below the daily maximum limitation. To achieve compliance, these values must result in a monthly average value at or below the monthly average limitation.

8.5.2 Selection of Percentiles

EPA calculates limitations based on percentiles chosen with the intention to be high enough to accommodate reasonably anticipated variability within the control of the facility and to be low enough to reflect a level of performance consistent with the Clean Water Act requirement that these effluent limitations be based on the "best" technologies. The daily maximum limitation is an estimate of the 99th percentile of the distribution of the *daily* measurements. The monthly average limitation is an estimate of the 95th percentile of the distribution of the *monthly* averages of the daily measurements.

The 99th and 95th percentiles do not relate to, or specify, the percentage of time a discharger operating the "best available" or "best available demonstrated" level of technology will meet (or not meet) the limitations. Rather, the use of these percentiles relates to the development of limitations. (The percentiles used as a basis for the limitations are calculated using the products of the long-term averages and the variability factors as explained in the next section.) If a facility is designed and operated to achieve the long-term average on a consistent basis and maintains adequate control of its processes and treatment systems, the allowance for variability provided in the limitations is sufficient to meet the requirements of the rule. The use of 99 percent and 95 percent represents a need to draw a line at a definite point in the statistical distributions (100 percent is not feasible because it represents an infinitely large value) and a policy judgment about where to draw the line that would ensure that operators work hard to establish and maintain the appropriate level of control. In essence, in developing the limitations, EPA has taken into account the reasonable anticipated variability in discharges that might occur at a well-operated facility. By targeting its treatment at the long-term average, a well-operated facility should be able to comply with the limitations at all times because EPA has incorporated into limitations an appropriate allowance for variability.

In conjunction with the statistical methods, EPA performs an engineering review to verify that the limitations are reasonable based on the design and expected operation of the control technologies and the facility process conditions. As part of that review, EPA examines the range of performance by the facility data sets used to calculate the limitations. Some facility data sets demonstrate the best available technology, and others demonstrate the same technology but not the best demonstrated design and operating conditions for that technology. For the latter facilities, EPA evaluates how the facility can upgrade its design, operating, and maintenance conditions to meet the limitations. If such upgrades are not possible, the limitations are modified to reflect the lowest levels that the technologies can reasonably be expected to achieve.

8.5.3 Compliance with Limitations

EPA promulgates limitations that facilities are capable of complying with at all times by properly operating and maintaining their processes and treatment technologies. However, the issue of exceedances or excursions (values that exceed the limitations) is often raised. Comments often suggest that EPA include a provision that a facility is in compliance with permit limitations if its discharge does not exceed the specified limitations, with the exception that the discharge may exceed the monthly average limitations 1 month out of 20 and the daily average limitations 1 day out of 100. This issue was, in fact, raised in other rules, including EPA's final Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) rulemaking. EPA's general approach in that case for developing limitations based on percentiles was the same as this rule and was upheld in *Chemical Manufacturers Association* v. *U.S. Environmental Protection Agency*, 870 F.2d 177, 230 (5th Cir. 1989). The Court determined the following:

> EPA reasonably concluded that the data points exceeding the 99th and 95th percentiles represent either quality-control problems or upsets because there can be no other explanation for these isolated and extremely high discharges. If these data points result from quality-control problems, the exceedances they represent are within the control of the plant. If, however, the data points represent exceedances beyond the control of the industry, the upset defense is available.
>
> Id. at 230.

More recently, this issue was raised in EPA's Phase I rule for the pulp and paper industry. In that rulemaking, EPA used the same general approach for developing limitations based on percentiles that it had used for the OCPSF rulemaking and for the proposed CAAP rule. This approach for the monthly average limitation was upheld in *National Wildlife Federation et al.* v. *Environmental Protection Agency*, No. 99-1452, Slip Op. at Section III.D (D.C. Cir.) (April 19, 2002). The Court determined that

> EPA's approach to developing monthly limitations was reasonable. It established limitations based on percentiles achieved by facilities using well-operated and controlled processes and treatment systems. It is therefore reasonable for EPA to conclude that measurements above the limitations are due to either upset conditions or deficiencies in process and treatment system maintenance and operation. EPA has included an affirmative defense that is available to mills that exceed limitations due to an unforeseen event. EPA reasonably concluded that other exceedances would be the result of design or operational deficiencies. EPA rejected Industry Petitioners' claim that facilities are expected to operate processes and treatment systems so as to violate the limitations at some pre-set rate. EPA explained that the statistical methodology was used as a framework to establish the limitations based on percentiles. These limitations were never intended to have the rigid probabilistic interpretation that Industry Petitioners have adopted. Therefore, we reject Industry Petitioners' challenge to the effluent limitations.

As that Court recognized, EPA's allowance for reasonably anticipated variability in its effluent limitations, coupled with the availability of the upset defense, reasonably accommodates acceptable excursions. Any further excursion allowances would go beyond the reasonable accommodation of variability and would jeopardize the effective control of pollutant discharges on a consistent basis and/or bog down administrative and enforcement proceedings in detailed fact-finding exercises, contrary to Congressional intent. See, for example, Rep. No. 92-414, 92d Congress, 2d Sess. 64, reprinted in *A Legislative History of the Water Pollution Control Act Amendments of 1972* (at 1482); *Legislative History of the Clean Water Act of 1977* (at 464-65).

EPA expects that facilities will comply with promulgated limitations *at all times*. If the exceedance is caused by an upset condition, the facility would have an affirmative defense to an enforcement action if the requirements of 40 CFR 122.41(n) are met. If the exceedance is caused by a design or operational deficiency, EPA has determined that the facility's performance does not represent the appropriate level of control (best available technology for existing sources; best available demonstrated technology for new sources). For promulgated limitations and standards, EPA has determined that such exceedances can be controlled by diligent process and wastewater treatment system operational practices such as frequent inspection and repair of equipment, use of backup systems, and operator training and performance evaluations.

8.6 ESTIMATION OF THE PROPOSED LIMITATIONS

In estimating the proposed limitations, EPA determines an average performance level (the "option long-term average" discussed in the next section) that a facility with well-designed, well-operated model technologies (which reflect the appropriate level of control) is capable of achieving. This long-term average is calculated from data from the facilities using the model technologies for the option. EPA expects that all facilities subject to the final limitations will design and operate their treatment systems to achieve the long-term average performance level consistently because facilities with well-designed, well-operated model technologies have demonstrated that this can be done.

In the second step of developing a limitation, EPA determines an allowance for the variation in pollutant concentrations when processed through extensive and well-designed production and treatment systems. This allowance for variance incorporates all components of variability, including shipping, sampling, storage, and analytical variability, and is incorporated into the limitations by using variability factors calculated from the data from the facilities using the model technologies. If a facility operates its treatment system to meet the relevant long-term average, EPA expects the facility will be able to meet the limitations. Variability factors assure that normal fluctuations in a facility's treatment are accounted for in the limitations. By accounting for these reasonable excursions above the long-term average, EPA's use of variability factors results in limitations that are generally well above the actual long-term averages.

Facilities that are designed and operated to achieve long-term average effluent levels used in developing the limitation should be capable of compliance with the limitations, which incorporate variability, at all times.

The following sections describe the calculation of the option long-term averages and option variability factors.

8.6.1 Calculation of Option Long-Term Averages

This section discusses the calculation of long-term averages by episode (episode long-term average) and by option (option long-term average) for each pollutant. These averages were used to calculate the limitations and as the option long-term averages for the pollutants of concern.

First, EPA calculated the episode long-term average by using either the modified delta-lognormal distribution or the arithmetic average (see Table 8.6-1 for the episode long-term averages). For the final rule, EPA intends to evaluate the appropriateness of the modified delta-lognormal distribution for these data and possibly consider other distributions such as the censored lognormal distribution (see Appendix F). In Appendix D, EPA has listed the arithmetic average (column labeled "Obs Mean") and the estimated episode long-term average (column labeled "Est LTA"). If EPA used the arithmetic average as the episode long-term average, the two columns have the same value.

Table 8.6-1. Episode Long-Term Averages and Variability Factors

Sub-category	*Option or Technology*	*Pollutant*	*Episode*	*Number of Data Points*	*Episode Long-Term Average (mg/L)*	*Episode Variability Factors*	
						Daily	*Monthly*
Flow-Through	OLSB	TSS	6297A	5	58.1037	1.6295	1.1933
			6297B	5	69.7312	1.3358	1.1091
			6460C	1	38.0000	n/a	n/a
		Total Phosphorus	6297A	5	10.1657	1.1281	1.0437
			6297B	5	9.4936	1.3719	1.1199
			6460C	1	0.3600	n/a	n/a
	Raceway	TSS	6297E	5	4.0000	n/a	n/a
			6460B	5	4.0000	n/a	n/a
		Total Phosphorus	6297E	5	0.1721	1.9026	1.3831
			6460B	5	0.0445	2.1131	1.3186
	1	TSS	6297G	5	4.5330	1.0645	1.0224
			6297H	5	4.6477	n/a	n/a
			6297I	5	4.1696	n/a	n/a
			6460A	5	9.5361	n/a	n/a
			DMR1	19	1.7814	2.9449	1.5141
			DMR3	37	3.6962	2.0935	1.3138
			DMR4	34	2.6764	3.7816	1.6997
		Total Phosphorus	6297G	5	0.2746	2.1236	1.3212
			6297H	5	0.2641	1.7196	1.2800
			6297I	5	0.1323	2.9745	1.5454
			6460A	5	0.0978	5.7387	2.1297
			DMR1	12	0.0932	5.6559	2.1113
	3	TSS	6460D	5	4.0000	n/a	n/a
			DMR2[a]	16	3.1236	5.1171	1.9920
		Total Phosphorus	6460D	5	0.0462	1.5830	1.1804
			DMR2	9	0.2146	6.1765	2.2280
Recir-culating	3	TSS	6439B[a]	5	47.0929	1.8709	1.2574
		BOD	6439B[a]	5	45.8269	1.2004	1.0671
		Total Phosphorus	6439B[a]	5	10.9182	1.9564	1.2793

Note: n/a means that the data set did not meet the requirements specified in Appendix E.
[a] As explained in Section 8.2, EPA excluded these data from developing the limitations.

Second, EPA calculated the option long-term average for a pollutant as the *median* of the episode long-term averages for that pollutant from selected episodes with the technology basis for the option (see Sections 8.1 and 8.2). The median is the midpoint of the values ordered (ranked) from smallest to largest. If there is an odd number of values (with n = number of values), the value of the (n + 1)/2 ordered observation is the median. If there are an even number of values, the two values of the n/2 and [(n/2)+1] ordered observations are arithmetically averaged to obtain the median value.

For example, for subcategory Y option Z, if the four (n = 4) episode long-term averages for pollutant X are:

Facility	Episode-Specific Long-Term Average
A	20 mg/L
B	9 mg/L
C	16 mg/L
D	10 mg/L

the ordered values are:

Order	Facility	Episode-Specific Long-Term Average
1	A	9 mg/L
2	B	10 mg/L
3	C	16 mg/L
4	D	20 mg/L

and the pollutant-specific long-term average for option Z is the median of the ordered values (the average of the 2nd and 3rd ordered values): (10 + 16)/2 mg/L = 13 mg/L.

The option long-term averages were used in developing the limitations for each pollutant within each regulatory option.

8.6.2 Calculation of Option Variability Factors

In developing the option variability factors used in calculating the limitations, EPA first developed daily and monthly episode variability factors using the modified delta-lognormal distribution. Table 8.6-1 lists the episode variability factors.

Appendix E describes the estimation procedure for the episode variability factors using the modified delta-lognormal distribution. For the final rule, EPA intends to evaluate the appropriateness of the modified delta-lognormal distribution for the CAAP data and possibly consider other distributions such as the censored lognormal distribution (see Appendix F). In addition to evaluating the distributional assumptions, EPA intends to evaluate whether autocorrelation is likely to be present in weekly measurements of wastewater data from the CAAP industry. When data are said to be autocorrelated, it means that measurements taken at specific time intervals (such as 1 week or 2 weeks apart) are related. For example, positive autocorrelation would be present in the data if the final effluent concentration of TSS was relatively high one week and was likely to remain at similar high values the next and possibly succeeding weeks. In some industries, measurements in final effluent are likely to be similar from one day (or week) to the next because of the consistency from day to day in the production processes and in final effluent discharges due to the hydraulic retention time of wastewater in basins, holding tanks, and other components of wastewater treatment systems. To determine if autocorrelation exists in the data, a statistical evaluation is necessary and will be considered before the final rule. To estimate autocorrelation in the data, many measurements for each pollutant would be required with values for equally spaced intervals over an extended period of time. If such data are available for the final rule, EPA intends to perform a statistical evaluation of autocorrelation and, if necessary, provide any adjustments to the limitations. This adjustment would increase the values of the variance and monthly variability factor used in calculating the maximum monthly limitation. However, the estimate of the long-term average and the daily variability factor (and thus the maximum daily limitation) are generally only slightly affected by autocorrelation.

After calculating the episode variability factors, EPA calculated the option daily variability factor as the *mean* of the episode daily variability factors for that pollutant in the subcategory and option. Likewise, the option monthly variability factor was the mean of the episode monthly variability factors for that pollutant in the subcategory and option. Table 8.6-2 lists the option variability factors.

Table 8.6-2. Option Long-Term Averages, Variability Factors, and Limitations

Subcategory	*Option or Technology*	*Pollutant*	*Option Long-Term Average (mg/L)*	*Option Variability Factors*		*Limitations (mg/L)*	
				Daily	*Monthly*	*Daily Maximum*	*Monthly Average*
Flow-through	OLSB	TSS	58.1	1.48	1.15	87	67
		Total Phosphorus	9.49	1.25	1.08	11.9	10.3
	Raceway	TSS	4.00	2.47	1.39	9.88	5.56
		Total Phosphorus	0.108	2.01	1.35	0.217	0.146
	1	TSS	4.17	2.47	1.39	11	6
		Total Phosphorus	0.132	3.64	1.68	0.482	0.222
	3	TSS	4.00	2.47	1.39	10	6
		Total Phosphorus	0.130	3.88	1.70	0.506	0.222
Recirculating	3	TSS *	–	–	–	50	30
		BOD	45.8	1.20	1.07	55.0	48.9
		Total Phosphorus	10.9	1.96	1.28	21.4	14.0

* Section 8.2 explains the derivation of these limitations.

8.6.3 Transfers of Option Variability Factors

After estimating the option variability factors, EPA identified one option (Option 3) and one technology (raceways) in the flow-through subcategory, for which variability factors for TSS could not be calculated. (See Table 8.6-3.) This resulted when all episode data sets had too few detected measurements to calculate episode variability factors (see data requirements in Appendix E). For example, if TSS had all ND values for all of the episodes in an option, it was not possible to calculate the option variability factors. In both cases, EPA calculated the limitations using the Option 1 variability factors from the flow-through subcategory. EPA determined that these variability factor transfers were appropriate because EPA would expect the effluent from a raceway and from a polishing pond (Option 3) to be less variable than the combined discharges from an OLSB and a raceway (Option 1).

Table 8.6-3. Cases Where Option Variability Factors Could Not Be Calculated

Subcategory	*Option or Technology*	*Pollutant*	*Source of Variability Factors*
Flow-through	Raceway	TSS	Option 1
	3	TSS	Option 1

8.6.4 Summary of Steps Used to Derive the Proposed Limitations

This section summarizes the steps used to derive the proposed limitations for TSS. EPA used these same steps to calculate the limitations that it considered for total phosphorus and BOD. For each pollutant in an option (or technology such as OLSB) for a subcategory, EPA performed the following steps in calculating the limitations:

Step 1 EPA calculated the *episode long-term averages* and *daily and monthly variability factors* for all selected episodes with the model technology for the option in the subcategory. (See Section 8.2 for selection of episodes and Table 8.6-1 for episode long-term averages and variability factors.)

Step 2 EPA calculated the *option long-term average* as the median of the episode long-term averages. (See Table 8.6-2.)

Step 3 EPA calculated the *option variability factors* for each pollutants as the mean of the episode variability factors from the episodes with the model technology. (See Table 8.6-2.) The option daily variability factor is the mean of the episode daily variability factors. Similarly, the option monthly variability factor is the mean of the episode monthly variability factors.

Step 4 For the pollutants for which Steps 1 and 3 failed to provide option variability factors, EPA determined variability factors on a case-by-case basis. (See Table 8.6-3.)

Step 5 EPA calculated each *daily maximum limitation* for a pollutant using the product of the option long-term average and the option daily variability factor. (See Table 8.6-2.)

Step 6 EPA calculated each *monthly average limitation* for a pollutant using the product of the option long-term average and the option monthly variability factor. (See Table 8.6-2.)

Step 7 EPA *compared* the daily maximum limitations to the data used to develop the limitations. EPA usually performs this comparison to determine whether it used appropriate distributional assumptions for the data used to develop the limitations (i.e., whether the curves EPA used provide a reasonable "fit" to the actual effluent data[5] or if there was an engineering or process reason for an unusual discharge). Except for one case, all proposed daily maximum limitations had greater values than the data used to develop the limitations. The exception was the TSS proposed daily maximum limitation for Option 1 in the flow-through subcategory. The single value exceeding the limitation was from episode 6460A on the day when the facility discharged from the OLSB. As explained in Section 8.2, during EPA's visit, the facility discharged the OLSB at a shorter than usual retention time. EPA also notes that the facility's OLSB would be considered to be underdesigned if it were the final treatment step at the facility. However, the facility has a polishing pond, which was designed to operate as a part of the overall treatment train at the facility, and thus the OLSB can be operated at less than maximum treatment efficiency and the effluent from this OLSB receives additional treatment prior to discharge.

8.7 REFERENCES

DynCorp, 2002. Memorandum: Conversion of Aquaculture Data for Episode 6297, from H. McCarty to C. Simbanin, July 24, 2002.

SAIC. (Science Applications International Corporation, Inc.) 2002a. Listings for Episode 6297: DMR Data, Summary Statistics, and Estimates, Falls Church, VA.

SAIC. (Science Applications International Corporation, Inc.) 2002b. Listing 5: Unaggregated Data for Pollutants of Concern, Falls Church, VA.

SAIC. (Science Applications International Corporation, Inc.) 2002c. Listing of the Aquatic, Solid, and Combined Filtrate Data for Facility 6297, Falls Church, VA.

SAIC. (Science Applications International Corporation, Inc.) 2002d. Listing 6: Individual Field Duplicate Sample Results for Pollutants of Concern, Falls Church, VA.

[5] EPA believes that the fact that the Agency performs such an analysis before promulgating limitations might give the impression that EPA expects occasional exceedances of the limitations. This conclusion is *incorrect*. EPA promulgates limitations that facilities are capable of complying with at all times by properly operating and maintaining their treatment technologies.

SAIC. (Science Applications International Corporation, Inc.) 2002e. Listing 7: Individual Grab Sample Results for Pollutants of Concern, Falls Church, VA.

USEPA. (U.S. Environmental Protection Agency) 2001. *Screener Survey for the Aquatic Animal Production Industry.* OMB Control No. 2040-0237 U.S. Environmental Protection Agency, Washington, DC.

USEPA. (U.S. Environmental Protection Agency) 2002. Memorandum: Censoring Assumptions for DMR Data in the Aquatic Animals Proposal, from M. Smith to M. Jordan, August 14, 2002.

CHAPTER 9
COSTING METHODOLOGY

9.1 INTRODUCTION

EPA identified several potential regulatory options for the concentrated aquatic animal production (CAAP) industry. This chapter describes the methodology used to estimate engineering compliance costs associated with installing and operating the treatment technologies and management practices considered for the regulatory options.

9.1.1 Regulatory Option Summary

EPA developed three regulatory options for CAAP facilities:

- Option 1—solids removal through treatment technologies and best management practices (BMPs).
- Option 2—BMP plan for pathogen control, prevention of nonnative species escapement, and minimization of drugs and chemicals.
- Option 3—additional solids control through treatment technologies.

Table 9.1-1 illustrates the treatment technologies and BMPs for each proposed option by subcategory. All three options were evaluated for Best Practicable Control Technology Currently Available (BPT)/Best Available Technology Economically Achievable (BAT) regulatory options. To determine the cost for complying with each option, EPA developed combinations of technologies and management practices that form the basis of the cost estimate for each type of CAAP facility production system under the BPT/BAT options. The combinations of treatment technologies and management practices are based primarily on the type of production system used at a facility. (See Chapter 5, Subcategorization of the Technical Development Document, for more information.) The type of production system determines the relative volume and strength of wastewater produced at a particular facility and the treatability of the wastewater using cost-efficient treatment technologies and management practices. The size of a facility (e.g., production level) determines the overall volume of water discharged and associated pollutant load. EPA used the type of production system and facility size in combination to determine the BMPs and treatment technologies that formed each proposed regulatory option.

Table 9.1-1. Treatment Technologies and BMPs for Proposed Regulatory Options, by Subcategory

Regulatory Option	*Required BMPs and Technologies*	*Subcategory*			
		Flow-through		*Recirculating*	*Net Pen*
		Medium[a]	*Large*[a]		
Option 1	Sedimentation basin	X	X	X	
	Quiescent zones	X	X		
	BMP plan	X	X	X	
	Compliance monitoring	X	X	X	
Option 2	Drug & chemical BMP plan		X	X	X
Option 3	Solids polishing		X	X	
	Compliance monitoring		X	X	
	Active feed monitoring				X

Note: "X" represents a required treatment technology or BMP component for an option.
[a]See section 9.3.1 for description of medium and large flow-through systems.

EPA proposed alternate compliance provisions for meeting the solids removal requirements for flow-through and recirculating systems. The first alternative requires specific numeric TSS limits (Table 9.1-2). These limits were determined for different discharge scenarios and levels of treatment options. The cost analysis included weekly monitoring and monthly reporting to show that a facility is meeting the requirements (see section 9.4 for more details on the cost assumptions) for monitoring and reporting. The second alternative allows facilities to develop and implement a BMP plan that will achieve the numeric limits. The BMP plan and its implementation would then be used as the measure of compliance, in lieu of the weekly monitoring and monthly reporting. EPA

Table 9.1-2. Summary of TSS Numeric Limits for Flow-through and Recirculating Systems

System/Discharge Type	*Maximum Daily (mg/L)*	*Maximum Monthly Average (mg/L)*
Flow-through; more than 475,000 lb annual production; full flow and single discharge	10	6
Flow-through; more than 475,000 lb annual production; offline settling, separate discharge	69	55
Flow-through; more than 100,000 lb, but less than or equal to 475,000 lb annual production; full flow and single discharge	11	6
Flow-through; more than 100,000 lb, but less than or equal to 475,000 lb annual production; offline settling, separate discharge	87	67
Recirculating; more than 100,000 lb annual production	50	30

believes that the alternate BMP plan approach could cost less than the monitoring and reporting approach. EPA does not believe that the BMP compliance alternative will cost any more than the estimated costs associated with the technology options described in this report. EPA did not perform any additional cost analysis for the BMP plan alternative.

9.1.2 Approach for Estimating Compliance Costs

EPA traditionally develops either *facility-specific* or *model facility* compliance costs and pollutant loading reduction estimates. Facility-specific compliance costs and pollutant loading reduction estimates require detailed process and geographic information about many, if not all, facilities in an industry. These data typically include production, capacity, water use, wastewater generation, waste management operations (including design and cost data), monitoring data, geographic location, financial conditions, and any other industry-specific data that might be required for the analyses. EPA then uses each facility's information to estimate the cost of installing new pollution controls and the expected pollutant removals from these controls.

When facility-specific data are not available, EPA develops model facilities to provide a reasonable representation of the industry. For the CAAP industry, EPA chose a model-facility approach to estimate compliance costs because detailed information about the scope of the CAAP industry was not available. EPA expects to obtain more detailed facility-level information, although not on every facility, through the detailed AAP survey (USEPA, 2002a).

EPA developed model facilities to reflect CAAP facilities with a specific production system, type of ownership, and (in many cases) species. The model facilities represented these facilities across a specific size range and were based on the average production value for all facilities represented within this range. These model facilities were based on data gathered during site visits, information provided by industry members and their associations, and other publicly available information. EPA estimated the number of facilities represented by each model using data from the Aquatic Animal Production (AAP) screener survey (Westat, 2002), in conjunction with information from the U.S. Department of Agriculture (USDA) 1998 Census of Aquaculture (USDA, 2000b). Costs and pollutant loading reductions were estimated for each model facility, and then industry-level costs were calculated by multiplying model facility costs by the estimated number of facilities required to implement the treatment technology or management practice in each model category.

EPA designed the model facility approach to capture the key characteristics (model facility configuration) of individual facilities, based on the Census of Aquaculture and the AAP screener survey, by averaging these key characteristics and then representing the averages as a model facility. Using this approach, every facility was characterized according to specific attributes, which included production system type, species, and dollar level of production. EPA estimated or calculated other key attributes for each of the model facilities, including system inputs (e.g., feed), estimated pollutant loads, discharge flow characteristics, and geographic data. All of these attributes and characteristics were then linked into option modules using Microsoft Excel as a computing platform to enable ease of changes to model facility assumptions and characteristics, as well as ease of calculation.

Control technology options and BMPs used to prevent the discharge of pollutants into the environment were linked with the unit cost modules, which calculated an estimated cost of the component based on estimates of capital expenses (which included elements such as engineering design, equipment, installation, one-time costs, and land) and annual operation and maintenance (O&M) expenses. For each model facility, EPA applied combinations of technologies and BMPs, given the model facility configuration characteristics (e.g., system type, size, and species). EPA adjusted the total cost of the component with a frequency factor that accounts for CAAP facilities that already have that technology or management practice in place. This adjusted cost, which reflects the number of facilities that would incur the costs associated with the technologies or management practices, is used to determine the estimated national capital and O&M costs for each model facility type.

9.1.3 Basic Model Assumptions

EPA based the compliance cost models on several primary assumptions:

- Feed offered to the cultured species contributes to pollutant discharges in two ways. First, metabolic wastes and unmetabolized feed consumed by the cultured species are contained in the feces and urine. Second, uneaten feed settles and increases the pollutant load in the culture water. Thus, feed inputs to the systems are the drivers of the quality of effluents from CAAP facilities.
- Feed conversion ratios (FCRs), although they vary among species and production systems, geographically, and by size or age of the animal, determine the amount of feed put into CAAP production systems. To determine the annual amount of feed used at a CAAP facility, EPA multiplied the annual production for a model facility by the FCR. EPA evaluated the technical literature for information about FCRs (Hochheimer and Westers, 2002a) and found the reported values to vary, especially by system type and species. EPA assumed that using average values for predominant species (e.g., catfish, trout, hybrid striped bass, and salmon), which are also the FCRs reported in the literature, in estimating pollutant loads and costs was a reasonable approach. The averages reflect some of the variation that occurs among species and within a system type. EPA used average FCRs for each production system to estimate the feed inputs, which translate into pollutant loads to a model facility (Table 9.1-3).

Table 9.1-3. Feed Conversion Ratios

System Type	*Initial FCR*	*Treatment/BMP*	*New FCR*
Ponds	2.2	—	—
Flow-through	1.4	—	—
Recirculating	1.6	—	—
Net pen	1.2	Active feed monitoring	1.0

Source: Hochheimer and Westers, 2002a.

- EPA received several comments from industry representatives regarding FCRs. The comments ranged from "FCRs are species- and site-specific" (Rice, 2002) to "FCRs are constantly changing" (Rheault, 2002). Several commenters thought the FCRs were too low (Engle, 2002; Pierce, 2002), and some thought EPA had estimated too high (Plemmons, 2002). As a result of these comments, EPA verified the assumed FCRs with other industry sources (Hinshaw, 2002, personal communication; MacMillan, 2002, personal communication). EPA will continue to evaluate the impact of different FCR assumptions.
- Technology options and BMPs have typical, definable, and steady-state efficiency rates of removing specific pollutants from water.
- Certain technologies are more applicable to some system types and flows than to others.

9.1.4 Organization of the Cost Chapter

The following costing information is discussed in detail in this chapter:

- *Section 9.2* presents the structure of the cost model. EPA's cost model for the CAAP industry uses the model facility approach to develop costs associated with each regulatory option.
- *Section 9.3* discusses the model facility configuration. This section also describes input data, including wastewater generation, pollutant inputs, and cost factors, for the model facilities for flow-through, recirculating, and net pen systems. EPA's cost model relies on specific information about the species raised, culture system, pollutant inputs, and wastewater generation rates to accurately predict the costs associated with each regulatory option.
- *Section 9.4* discusses unit cost modules, which are components of the treatment technologies and BMPs that compose the regulatory options. Each treatment technology or BMP cost module contains formulas by which to calculate the costs associated with each regulatory option based on the facility characteristics.
- *Section 9.5* describes the current frequency of existing BMPs and treatment technologies at CAAP facilities. EPA used this occurrence frequency, or frequency factor, to estimate the portion of the operations that would not incur costs to comply with the new regulation.
- *Section 9.6* provides output data.
- *Section 9.7* describes the evolution and changes EPA made to the costing methodology.

9.2 COST MODEL STRUCTURE

EPA estimated the costs associated with regulatory compliance for each of the regulatory options under consideration. The estimated costs of compliance to achieve the proposed requirements include initial capital costs, in some cases, as well as annual O&M and monitoring costs. EPA estimated compliance costs based on the cost of implementing the BMPs or control technologies that have been shown to meet particular requirements, as demonstrated by facilities in the CAAP facility industry.

To generate industry compliance cost estimates associated with each regulatory option for AAP facilities, EPA developed a computer-based model made up of several individual cost modules. Figure 9.2-1 illustrates the cost model by showing that it consists of several components, which can be grouped into four major categories:

- Model facility configuration
- Unit cost of treatment technology or BMP
- Frequency factors
- Output data

Each module calculates costs and loading data for a specific wastewater treatment technology or BMP (e.g., a primary settling basin) based on model facility characteristics. Frequency factors are then applied to the component costs to weight the costs by the estimated percentage of operations that already have that treatment technology or practice in place. These weighted facility costs are then summed for each regulatory option and model facility. All costs are in year 2000 dollars.

9.2.1 Model Facility Configuration

The model facility configuration part of the cost model sets up the characteristics of each unique model facility, based primarily on system type, species, the combination of existing and proposed management practices and technologies, capital costs (e.g., land costs, regional differences in technology implementation costs), annual production, and feed inputs.

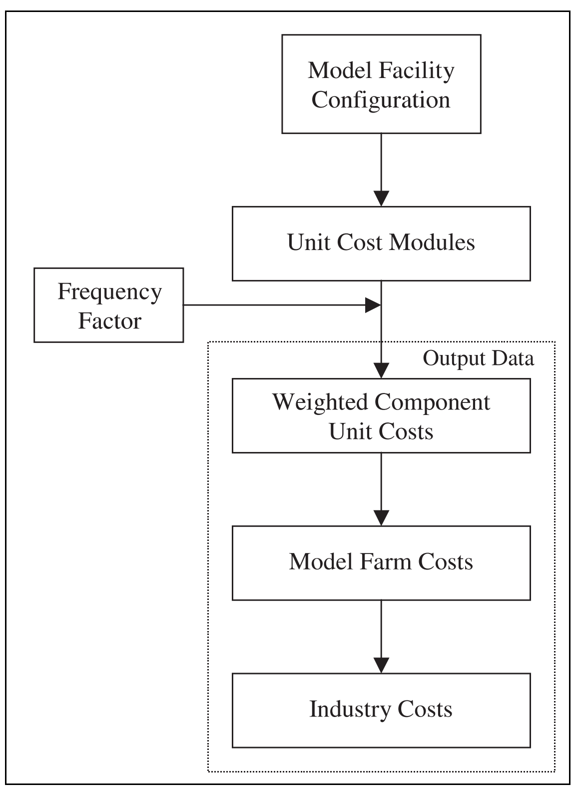


Figure 9.2-1. Schematic of Cost Model Structure

Input data to the model facilities include the following:

- Number of facilities for a combination of system types, sizes, culture species, facility types, and locations.
- Technologies and BMPs.
- National average capital cost, land requirements of technology options, and BMPs.
- Average flow (daily).
- Estimates of annual production and price per pound.
- Data associated with feeding practices, including feeding in pounds per day and pollutant concentrations associated with feed.

9.2.2 Unit Cost of Treatment Technologies or BMPs

9.2.2.1 Unit Cost Components

The unit cost component of treatment technologies or BMPs (unit cost modules) contains the cost information for each component (BMP or treatment technology) contained in the regulatory options. The cost modules calculate the various capital and O&M costs for the model facilities, based on culture species and production system, using various cost factors for labor, electricity, and land values for each of the regulatory options. Section 9.3 describes the various cost factors. The unit cost modules are used in conjunction with the frequency factors (see Section 9.5) to determine the costs for each segment of the industry.

9.2.2.2 General Cost Assumptions

Most of the input data for each model facility are specific to the species cultured and the production system, such as facility size, annual production, or unit sizes. Some cost input, however, is independent of the species and culture system. EPA assumed a management labor rate of $13.46/h, based on government labor statistics for full-time employees in the agricultural industry (Department of Labor, 2001). EPA assumed a general labor rate of $7.69/h, based on government labor statistics for full-time employees in the agricultural industry (Department of Labor, 2001). For cost estimates, EPA assumed average land values of $1,050/ac (USDA, 2000a). The value is the average U.S. farm real estate value, including all land and buildings for the continental United States in the year 2000 (USDA, 2000a). For cost estimates EPA assumed an electricity cost of $0.0722/kWh (EIA, 2002). The value is the average retail revenue per kilowatt-hour in the continental United States in the year 2000 (EIA, 2002). Additional costing impacts are species- or system-specific and are described in Sections 9.3.1 through 9.3.4.

9.2.3 Frequency Factors

EPA recognized that some individual facilities have already implemented some of the treatment technologies or BMPs included as part of the proposed options. When estimating costs and pollutant loadings for implementing the proposed options across the entire subcategory nationwide, EPA did not include costs or pollutant removals for BMPs or treatment technologies already in place.

EPA determined the current frequency of existing BMPs and treatment technologies at CAAP facilities based on existing NPDES permit requirements, screener survey responses, site visits, and sampling visits and information provided by the industry. This occurrence frequency was used to estimate the portion of the operations that would not incur costs to comply with the new regulation. Frequency factors are discussed in greater detail in Section 9.5.

9.2.4 Output Data

Output data from the cost model provide economic estimates for incremental pollution control in the CAAP industry. Capital and one-time costs, annual O&M costs, and pre-tax annualized costs were calculated for each subcategory and, more specifically, by option and facility size. From the cost model EPA also estimated the pre-tax annualized cost of the proposed options, based on the screener survey facility counts, and summed the pre-tax annualized costs for all of the proposed options to estimate the national pre-tax annualized cost of the proposed options. The national pre-tax annualized costs, which were used to evaluate the economic affordability of the regulation, are estimates of the annual costs that an individual facility would incur as a result of the proposed regulation.

9.3 MODEL FACILITY CONFIGURATION

EPA defined model facilities for flow-through, recirculating, and net pen systems based on species, ownership (e.g., commercial, federal, state), and facility production size.

9.3.1 Flow-through Systems

Flow-through systems are located where water is abundant, which allows farmers to produce fish that require continuous supplies of high-quality water. Discharges from flow-through systems can be low in concentrations of pollutants, primarily because of the high flow rates. Flow-through systems require a high volume of water to flush wastes from the production area and make oxygen available to the aquatic animals. Most flow-through systems are designed and operated with water flows that exchange or replace water in the system tanks or raceways 3 to 6 times per hour (Hinshaw and Fornshell, 2002), which translates into a system flow rate of 100 gal/min per pound of annual production (Hochheimer and Westers, 2002b).

For flow-through systems, EPA developed model facilities for two production groups. EPA determined the production levels based on an initial analysis of cost and economic impacts. EPA based this initial cost estimate on model facilities derived from revenue categories (Hochheimer and Moore, 2002) using the Census of Aquaculture (USDA, 2000b). EPA used the results of this initial analysis to arrive at the production thresholds for medium and large facilities. Data from the AAP screener survey (Westat, 2002) representing a species, lifestage (e.g., food-size or stockers), and facility type (e.g., commercial, federal, state) were sorted into two production groups, facilities that produce 100,000 lb up to 475,000 lb (medium) and facilities producing 475,000 lb or more (large) annually. All of the facilities from the AAP screener survey that fell within a species-lifestage-facility type combination for medium and large facility size classes were then averaged to produce the model facility. For example, all seven of the federal (facility type) facilities that produce trout (species) stockers (lifestage) in flow-through systems that annually produce 100,000 lb up to 475,000 lb were grouped as medium facilities.

EPA used average production values for the facilities grouped within a specific model facility to reflect the distribution of facilities reported in the AAP screener results. An example of how EPA calculated average model facility size, using trout-stockers-federal, is provided in Table 9.3-1. In this example, the range of facility sizes is 106,788 to 309,885 lb, with an average of 208,296 lb.

Table 9.3-1. Model Facility Production Calculation: Trout-Stockers-Federal

Facility Number	*Facility Production (lb/yr)*
Facility 1	106,788
Facility 2	121,600
Facility 3	198,400
Facility 4	214,400
Facility 5	230,850
Facility 6	276,152
Facility 7	309,885
Average model facility size	208,296

Based on industry input (Hinshaw, 2002, personal communication; Plemmons, 2002), EPA assumed a loading density of 3 lb/ft^3 for sizing of facilities (determining the estimated number of raceways for a given facility size). EPA assumed the raceway size for medium facilities to be 150 ft long by 14 ft wide by 3 ft deep (volume = 6,300 ft^3). The raceway size for large facilities was assumed to be 175 ft long by 18 ft wide by 3 ft deep (volume = 9,450 ft^3). The number of raceways is a factor in many of the cost estimates. EPA believes the sizes and loading densities are reasonable for medium and large flow-through systems. To estimate the number of raceways at a flow-through facility, EPA used the following calculation:

> Number of raceways = annual production/(loading density * volume per raceway)

Where:

- Number of raceways is the number for a model facility type (rounded up to the nearest integer)
- Annual production is the average production for the model facility type in pounds
- Loading density is 3 lb/ft^3 (Hinshaw, 2002, personal communication; Plemmons, 2002)
- Volume per raceway is 6,300 ft^3 for medium facilities and 9,450 ft^3 for large facilities

EPA developed raceway configurations from information obtained during site visits and conversations with AAP industry representatives (Hinshaw, 2002, personal communication; Tetra Tech, 2002d; Tetra Tech, 2002f; Tetra Tech, 2002g; Tetra Tech, 2002h; Tetra Tech, 2002i; Tetra Tech, 2002j; Tetra Tech, 2002k; Tetra Tech, 2002l; Tetra Tech, 2002m; Tetra Tech, 2002n;). For the purpose of costing, EPA developed models for flow-through systems assuming raceways would be concrete. Site visits and screener data indicated smaller flow-through facilities also operate circular tanks, earthen raceways, and flow-through concrete or earthen ponds (Tetra Tech, 2002d; Tetra Tech, 2002e; Tetra Tech, 2002f; Tetra Tech, 2002g; Tetra Tech, 2002h; Tetra Tech, 2002i; Tetra Tech, 2002j; Tetra Tech, 2002k; Tetra Tech, 2002l; Tetra Tech, 2002m; Tetra Tech, 2002n). EPA assumed that raceways are the predominant systems used in flow-through facilities at the sizes being considered for this proposed regulation.

For the purpose of costing, EPA also assumed costs for non-raceway flow-through systems to be comparable to those for concrete raceway systems. For flow-through system facilities that do not use raceways, there are a variety of alternatives for collecting solids to remove them from the discharge. Circular tank systems often use dual drains to take advantage of the settling and concentrating of solids around a bottom center drain. In a dual drain system, overflow water is typically drained at a location above the tank bottom to control water levels in the tank. This primary drain discharges most of the flow and typically has low concentrations of solids. The second drain, at the bottom center of the tank, discharges the higher concentrated solids portion of the effluent. The bottom drain can be constructed to continually discharge a small volume of water with the concentrated solids or to be manually opened to discharge the concentrated solids. Summerfelt and others (2000) provides additional information on drains for circular tanks.

The number of facilities represented by each flow-through model facility group is indicated in Table 9.3-2. EPA found nothing to indicate that the wide range of facility sizes represented by the average production values used as input for the model facilities grouped as “large” would misrepresent the range of facilities that made up the class. Although the larger facilities can realize economies of scale in production costs, EPA did not find any differences in waste treatment or effluent quality characteristics at the larger systems in the range. Thus, EPA assumed the average facility sizes could accurately represent the range of facilities in the size class. (This observation holds for the ranges in facility sizes for recirculating and net pen systems as well.)

Table 9.3-2. Model Facility Information

Model Facility	*Size*	*Number of Facilities*[a]	*Production Range (lb/yr)*[b]	*Average Production (lb/yr)*[b]
Trout-Commercial-Flow-through	Medium	22	100,000-370,000	208,986
	Large	8	592,900-8,260,815	2,499,170
Trout-State-Flow-through	Medium	< 5	—	—
	Large	< 5	—	—
Trout-Stockers-Commercial-Flow-through	Medium	5	128,000-317,000	192,137
Trout-Stockers-Federal-Flow-through	Medium	7	106,788-309,885	208,296
	Large	< 5	—	—

Model Facility	Size	Number of Facilities[a]	Production Range (lb/yr)[b]	Average Production (lb/yr)[b]
Trout-Stockers-State-Flow-through	Medium	44	100,800-433,915	224,193
	Large	< 5	—	—
Trout-Stockers-Other-Flow-through	Medium	< 5	—	—
	Large	< 5	—	—
Tilapia Commercial-Flow -through	Medium	< 5	—	—
	Large	< 5	—	—
Striped Bass Commercial-Flow-through	Medium	< 5	—	—
Salmon-Other-Flow-through	Large	< 5	—	—

a < 5 indicates a group with fewer than five facilities and is reported in this manner to protect the confidentiality of the individual facilities.
b Model facility groups with fewer than five facilities are not reported.

Common industry BMPs and treatment technologies observed at flow-through production facilities include:

- Feed management
- Solids management BMP plan
- Raceway cleaning[1]
- Mortality removal
- Quiescent zones
- Quiescent zone cleaning
- Primary settling
- Vegetated ditches
- Land application of collected solids

9.3.2 Alaska Flow-through Systems

Alaska's salmon producers refer to production operations as "ocean ranching" in which hatchery fish are released into coastal areas to supplement the natural populations. Government and nonprofit organizations operate these facilities, which commercial and recreational fishermen support through fees.

[1] Raceway cleaning removes accumulated solids (biofouling and adhering feces or uneaten feed) from the raceways. The frequency of cleaning depends on factors such as temperature, sunlight, feed type, and size of the cultured species and can range from once every 2 to 3 weeks to once per growing cycle. Operators typically brush the walls and bottom of the raceway and port the solids-laden water to a sedimentation basin.

Alaska's salmon production systems represent a slight departure from traditional flow-through culture systems. Because of the high costs associated with the disposal of solids and tidal flushing in the waters adjacent to the facilities, most facilities do not operate wastewater treatment units for the collection of solids. Otherwise, the facilities operate much like all other flow-through systems.

Because facility-specific data were available for the Alaskan facilities, EPA analyzed each facility separately to determine compliance costs. EPA estimated production data for each facility using 2000 hatchery production data reported in Alaska Fish and Game's *Alaska Salmon Enhancement Program 2000 Annual Report* (McNair, 2001). EPA estimated hatchery releases by facilities using a conversion of 0.4 g per fish for pink and chum salmon and 20 g per fish for coho, chinook, sockeye, and other salmon species, based on industry-provided information (Tetra Tech, 2002a).

Only the facilities producing 100,000 lb/yr or more were modeled. Table 9.3-3 shows production estimates for the Alaska salmon facilities producing more than 100,000 lb/yr.

Table 9.3-3. Alaskan Salmon Producers

Facility	*Production (lb/yr)*	*Facility*	*Production (lb/yr)*
Facility 1	104,738	Facility 10	207,649
Facility 2	201,052	Facility 11	985,194
Facility 3	204,139	Facility 12	116,636
Facility 4	144,436	Facility 13	366,030
Facility 5	135,510	Facility 14	244,543
Facility 6	403,515	Facility 15	571,095
Facility 7	150,822	Facility 16	145,089
Facility 8	125,720	Facility 17	222,290
Facility 9	153,371	Facility 18	250,047

EPA used Alaska-specific data for the general cost (electricity rates, land values, and labor rates). The Energy Information Association (EIA, 2002) reports average electricity rates in 2000 for Alaska as $0.093/kWh. Land costs were estimated from a report on habitat and restoration of stream bank property, which valued land at an average of $12,024 ($12,697 in 2000 dollars) per acre (Alaska Department of Fish and Game, 2002). In 2000, Alaska's labor rates for managers were $21.38/h and for general labor were $15.03/h (Alaska Department of Labor and Workforce Development, 2002).

EPA used the following assumptions to estimate compliance costs at Alaska facilities:

- Loading densities are estimated at 3 lb/ft^3.
- Raceway size is 150 ft long by 14 ft wide by 3 ft deep, which is the same size as medium-sized flow-through facilities in other states.

- Flow rate is 100 gal/min per pound of production, which is the same rate as that of medium-sized flow-through facilities in other states.

Common Alaska salmon industry BMPs and treatment technologies include:

- Feed management
- Raceway cleaning

9.3.3 Recirculating Systems

Recirculating systems typically require inputs of relatively small volumes of water because water in these systems is continuously filtered and reused. Internal biological filtration processes remove ammonia, mechanical filters remove solids, and other life-support equipment adds oxygen and alkalinity to the system water. The production water treatment process is designed to minimize water requirements, which results in a small-volume, concentrated waste stream that is discharged daily. Many recirculating systems are operated with a 10% makeup volume of water added daily to dilute the production water and replace water lost to evaporation and backwashing of the solids filters (Chen et al., 2002). Thus, recirculating systems have a continuous discharge consisting of the backwash from the solids filter and overflows resulting from the added makeup water.

The loading density was indicated by the average stocking density of the culture species within the production system at maximum production levels. Information from site visits conducted at facilities operating recirculating production systems indicated loading densities of about 1 lb per gallon of culture water (Tetra Tech, 2002b; Tetra Tech, 2002o; Tetra Tech, 2002p; USEPA, 2002d).

EPA calculated the production system volume for recirculating systems using the model facility's annual production and loading density. The formula used to calculate production system volume is as follows:

Production system volume = facility annual production/loading density

where production system volume is reported in gallons, loading density is 1.0 lb/gal (Tetra Tech, 2002b; Tetra Tech, 2002o; Tetra Tech, 2002p), and facility annual production is the average annual model facility production in pounds. Since many recirculating system operators add about 10% of the system volume per day, EPA assumed that recirculating systems would generate a daily discharge volume of about 10% of the system volume. For systems that add less make-up water, then this assumption is a conservative estimate of the volume of effluent requiring treatment on a daily basis.

For recirculating systems EPA developed one model facility to represent all facilities having a production level equal to or greater than 100,000 lb/yr. EPA grouped data from the AAP screener survey (Westat, 2002) representing a species, lifestage (e.g., food-size or stockers), and facility type (e.g., commercial, federal, state) combination into model facility groups representing facilities annually producing 100,000 lb or more (large). All of the species-lifestage-facility type combinations for the large facility size class were then averaged to produce the model facility. Table 9.3-4 provides an example of how

EPA calculated production for a model facility, using tilapia-food-size-commercial. Table 9.3-5 shows the number of facilities represented by each recirculating model.

Table 9.3-4. Model Facility Production Calculation: Tilapia-Food-size-Commercial

Facility Number	*Facility Production (lb/yr)*
Facility 1	Range: 300,000 to 525,000
Facility 2	
Facility 3	
Facility 4	
Facility 5	
Average model facility size	351,634

Table 9.3-5. Model Facility Information

Model Facility	*Size*	*Facilities Represented*
Tilapia-Recirculating	Large	5
Striped Bass-Recirculating	Large	< 5[a]

[a] < 5 indicates a group with fewer than five facilities and is reported in this manner to protect the confidentiality of the individual facilities.

Common industry BMPs and treatment technologies at recirculating production facilities include:

- Feed management
- Solids management BMP plan
- Mortality removal
- Primary settling
- Microscreen filtration
- Biological treatment

9.3.4 Net Pen Systems

Net pen systems are suspended or floating holding cages or nets used for the growout of the culture species. The systems may be located along a shore or pier or may be anchored and floating offshore. Net pens rely on tides and currents to provide a continual supply of high-quality water to the cultured animals. For most locations the structural design of net pens must consider the potential high-energy environment in open waters, especially during storms. Net pens are designed to withstand such high-energy environments and are anchored to keep them in place during extreme weather events. Net pen systems are located in coastal bays or estuaries where tidal or river flow is abundant.

For net pen systems EPA developed one model facility to represent all facilities having a production level equal to or greater than 100,000 lb. EPA sorted data from the AAP screener survey representing a species, lifestage (e.g., food-size), and facility type (e.g., commercial, federal, state) into facilities producing 100,000 lb or more (large) annually. All of the species-lifestage-facility type combinations for the large facility size class were then averaged to produce the model facility. Table 9.3-6 provides an example of how EPA calculated production for a model facility.

Table 9.3-6. Model Facility Production Calculation: Salmon-Food-size-Commercial

Facility Number	***Facility Production (lb/yr)***
Facility 1	Range: 342,380 – 6,352,715
Facility 2	
Facility 3	
Facility 4	
Facility 5	
Facility 6	
Facility 7	
Facility 8	
Average model facility size	2,387,086

EPA estimated that a loading density of 0.8 lb/ft^3 was applicable to the industry (Hochheimer and Westers, 2002c). The volume of individual nets was assumed to be 250,000 ft^3, based on site visit information (Tetra Tech, 2002c; Tetra Tech, 2002s). To estimate the number of net pens at a facility, EPA used the following calculation:

Number of net pens = annual production/(loading density * volume per net pen)

Where:

- Number of net pens is the number for a model facility type (rounded up to the nearest integer)
- Annual production is the average production for the model facility type in pounds
- Loading density is 0.8 lb/ft^3
- Volume per net pen is 250,000 ft^3 for all facilities

Common industry BMPs and treatment technologies at net pen production facilities include:

- Feed management
- Solids management BMP plan
- Mortality removal
- Active feed monitoring

- Double netting
- Net maintenance (removal of fouling organisms)

9.4 Unit Cost of Treatment Technologies and BMPs

Cost modules calculate the direct capital and annual costs for installing, operating, and maintaining a particular technology or practice for an AAP facility. Each cost module determines an appropriate design of the system component based on the characteristics of the model facility and the specific regulatory option. Waste volumes generated by the model facility spreadsheets were used to size equipment and properly estimate the direct capital costs for purchasing and installing equipment and annual O&M costs.

Estimates of capital and annual cost components are based on information collected from the USDA 1998 Census of Aquaculture (USDA, 2000b), screener surveys, literary references, technical reports, EPA site and sampling visits, and estimates based on standard engineering methods of cost estimation (Hydromantis, 2001; Metcalf and Eddy, 1991). The following subsections describe each technology or BMP cost module used as a basis for the regulatory options and specifically discuss the following:

- Description of technology or practice
- Design
- Cost

9.4.1 Quiescent Zones

Quiescent zones are a technology control considered in Option 1 for all flow-through CAAP facilities as a part of primary solids removal.

9.4.1.1 Description of Technology or Practice

Quiescent zones are a practice used in raceway flow-through systems in which the last approximately 10% of the raceway serves as a settling area for solids. It is important to note that flow-through system raceways are typically sized according to loading densities (e.g., 3 to 5 lb of fish per cubic foot), but the flow rate of water through the system drives the production levels in a particular raceway. Thus, EPA evaluated the impacts of placing quiescent zones in the lower 10% of raceways and found no adverse impacts on the production capacity of a facility (Hochheimer and Westers, 2002b). The goal of quiescent zones and other in-system solids collection practices is to reduce the total suspended solids (TSS) and associated pollutants in the effluent. Estimates of quiescent zone pollutant reductions were based on information supplied by AAP industry representatives (Hinshaw, 2002, personal communication; MacMillan, 2002, personal communication).

Quiescent zones usually are constructed with a wire mesh screen that extends from the bottom of the raceway to above the maximum water height to prohibit the cultured species from entering the quiescent zone. The reduction in the turbulence usually caused by the swimming action of the cultured species allows the solids to settle in the quiescent zone. The collected solids are then available to be efficiently removed from the system. Quiescent zones are usually cleaned on a regular schedule, typically once per week in medium to large systems (Hinshaw, 2002, personal communication; MacMillan, 2002, personal communication), to remove the settled solids. The Idaho BMP manual (IDEQ, n.d.) recommends a minimal quiescent zone cleaning frequency of once per month in upper raceways and twice per month in lower units. The settled solids must be removed regularly to prevent breakdown of particles and leaching of pollutants such as nutrients and biochemical oxygen demand (BOD).

Quiescent zones placed at the bottom or end of each rearing unit or raceway allow for the settling of pollutants before they are discharged to other production units (when water is serially reused in several rearing units) or receiving waters.

Operational factors associated with operating quiescent zones include the following:

- The necessity to clean the screens to prevent fouling and damming of water in the raceway.
- The regular removal of collected solids from the quiescent zones. Timely cleaning involves the dedication of the needed resources to regularly clean the quiescent zones. Facilities must also have the equipment needed to clean the quiescent zones regularly.

Quiescent zones increase labor inputs because of the need to remove collected solids regularly and maintain the screens that exclude the culture species. Cleaning of the quiescent zones also creates a highly concentrated waste stream that should be treated before it is discharged into a receiving water body.

9.4.1.2 Design

Quiescent zones are designed to exclude fish from the lower portion of the raceway. The influent side of the quiescent zone usually has a wire mesh screen that extends from the bottom of the raceway to above the maximum water height to prohibit the cultured species from entering the quiescent zone and disturbing the settled solids. Most designs use channels cut into the concrete sides of a raceway to retain the screen and might also require a center column to support the screen frame in wider raceways. Water leaving the effluent end of the quiescent zone is controlled with dam boards installed across the width of the raceway. The dam boards are stacked to regulate the height of water in the raceway. Water flows slowly from the entire width of the raceway at the top of the water column so that the settled solids are not disturbed. A drain is installed in the bottom of the quiescent zone for cleaning the accumulated solids. A standpipe, which is higher than the height of the dam boards, prevents water from entering the drain under normal operation. When cleaning is desired, the standpipe is pulled and a vacuum hose is attached to the drain. The solids are then vacuumed into the drain for additional treatment.

9.4.1.3 Capital Costs

For the purpose of estimating capital costs, EPA assumed that the costs for quiescent zones in both medium and large systems are based on construction that rebuilds approximately 100 ft^2 of surface area in the lower portion of the raceway to install a drain and to cut channels for the screens and dam boards. Even though raceway widths vary among facilities, EPA assumed a constant construction disturbed area of 100 ft^2 because the installation of drains should require disturbing about the same size area independent of the actual width of the raceway. This construction could result in excavation to a depth of 3.5 ft. The rebuilding of the lower portion of the raceway includes the installation of channels to hold the fish exclusion screen and dam boards, as well as reconstruction of the drain structure to allow for water level management and drains for cleaning the solids.

EPA assumed that, in the worst case, a facility would have raceways with the bottom of the slab 3.5 ft below grade. This would necessitate the following excavation volume:

$$\text{Excavation volume} = \frac{100\ ft^2 \times 3.5\ ft}{27\ ft^3/yd^3} = 13\ yd^3$$

where the excavation volume is in cubic yards.

The excavation cost would then be:

$$\text{Excavation cost} = 13\ yd^3 \times \$5.70/yd^3 = \$74.10$$

where excavation cost is in dollars and the cost per cubic yard ($\$5.70/yd^3$) is from RS Means (2000).

The quiescent zone walls and floor were considered to be constructed with concrete and have an 8-in. thickness. Concrete used in the wall and floor construction was estimated to cost $73.50 per cubic yard installed (RS Means, 2000). EPA observed several different drain and quiescent zone configurations during the site visits at flow-through system facilities. The design that required the most concrete included a concrete dam (across the width of the raceway and lower than the outside wall height) that acts as a water level control. For the purpose of estimating costs, EPA assumed this quiescent zone design would require the addition of the equivalent of four walls (the two sides, the end, and the dam) at the tail end of a raceway. The volume of concrete required for the concrete walls and floor was computed using the following two equations:

Concrete required = (wall length * wall height * wall thickness * 4) + (floor surface area * floor thickness)

Concrete costs = concrete required * concrete costs ($\$/yd^3$)

Where:

Wall length = the length of one wall of the quiescent zone

Wall height = the height of the quiescent zone

Wall thickness = the thickness of the concrete wall

Floor thickness = the thickness of the concrete floor

EPA assumed that the concrete would be reinforced with reinforcing steel bar (Rebar), which would add 10% to the concrete costs (Swanson, 2002). The rebar costs were computed as follows:

Rebar costs = concrete costs * 10%

EPA assumed that facilities installing quiescent zones would also install offline settling basins and that the costs for additional piping were part of the estimates for the settling basins (see Section 9.4.2). Water and solids in the quiescent zone are suctioned into the drain (assuming gravity flow) and conveyed under the raceway to the feeder pipe leading to the sedimentation basin. Screens are cleaned as part of the quiescent zone cleaning at intervals of no more than 2 weeks.

9.4.1.4 Operation and Maintenance Costs

Facilities using quiescent zones must clean the accumulated solids at least every 2 weeks to prevent breakdown of the solids and resuspension in the effluent. Most facilities can use gravity flow to pull a vacuum, which can be used to suction out accumulated solids in quiescent zones and transport them to the offline settling basin. EPA assumed quiescent zones could be cleaned with gravity flows and the cleaning would not require pumps or electrical costs. Vacuums connect to the drain line of the raceway that runs to the sedimentation basin and are made from PVC plastic pipe fittings and PVC flexible hoses. To vacuum a raceway, the standpipe normally in the drain is pulled and one end of the vacuum inserted. Solids are then vacuumed from the quiescent zone by the water flowing into the flexible hose. The cost for materials to construct a vacuum is assumed to be $500 per year. The vacuum component costs are an annual cost because of the normal wear on the vacuum. For the purpose of estimating O&M costs, EPA used information collected during the sampling program for the CAAP industry that indicated facility personnel spend about 20 to 30 minutes per week per raceway cleaning and maintaining quiescent zones (Tetra Tech, 2002d). EPA estimated this cost using general labor at a rate of 5 minutes per raceway 6 d/wk (312 d/yr). EPA found 6-d workweeks to be the prevalent practice among the facilities visited during the site visits, so 312 d was used as the standard number of working days for general labor for O&M activities. The equation for all quiescent zone O&M, including cleaning, is as follows:

> Raceway O&M labor costs = number of raceways * 5 minutes per day * 312 days/year * general labor rate

where the raceway O&M costs are in dollars per year, the number of raceways is estimated in the model configuration, and the general labor rate is $7.69/h.

The cost for screens is assumed to be $100 per raceway per year. Screens are constructed with a metal or wood frame to hold the screen and can be made of metal or plastic mesh. One screen that spans the width of the raceway and is about 6 inches higher than the water depth is required for each raceway. Adding wooden dam boards after the screen can also enhance settling. The cost for the dam boards is assumed to be $20 per raceway per year (Hochheimer, 2002).

9.4.2 Sedimentation Basins (Gravity Separation)

Sedimentation basins are a technology control considered in Option 1 for all flow-through and recirculating CAAP facilities as a part of primary solids removal. Sedimentation basins at flow-through facilities can be in the form of offline or full-flow basins. Offline settling treats a portion of the flow-through effluent volume in which solids have been concentrated. When offline settling is used, treatment technologies to concentrate solids (e.g., quiescent zones) are also used. Full-flow settling treats the entire flow-through effluent volume. For recirculating systems, sedimentation basins are used to treat the waste stream discharged from the recirculating system.

9.4.2.1 Description of Technology or Practice

Sedimentation, also known as settling, separates solids from water using gravity settling of the heavier solid particles (Metcalf and Eddy, 1991). In the simplest form of sedimentation, particles that are heavier than water settle to the bottom of a tank or basin. Sedimentation basins (also called settling basins, settling ponds, sedimentation ponds, or sedimentation lagoons) are used extensively in the wastewater treatment industry (Metcalf and Eddy, 1991) and are commonly found in many flow-through and recirculating CAAP facilities (Westat, 2002). Most sedimentation basins are used to produce a clarified effluent (for solids removal), but some sedimentation basins remove water from solids to produce a more concentrated sludge. Both of these applications of sedimentation basins are used and are important in CAAP systems.

Periodically, when accumulating solids exceed the designed storage capacity of the basin, the basin is cleaned of the accumulated solids. EPA found that the cleaning frequencies of sedimentation basins used at CAAP facilities ranged from 2 to 12 times per year depending on the size of the facility (Jackoviac, 2002, personal communication; MacMillan, 2002, personal communication). For estimating costs EPA used a cleaning frequency of nine times per year to capture some of the variation in cleaning frequencies used by the industry. By sizing sedimentation basins for a cleaning frequency of 9 times per year, the basin volume is larger than that for a cleaning frequency of 12 times per year. The extra storage also provides a safety factor to accommodate facilities that cannot use a solids disposal method such as land application, which requires year-round access to application sites.

The primary advantages of sedimentation basins for removing suspended solids in effluents from CAAP systems are the relative low cost of designing, constructing, and operating sedimentation basins; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. In many aquatic animal production systems, most of the solids from feces and uneaten feed are of sufficient size to settle efficiently in most moderately sized (37 ft^3 to 741 ft^3) sedimentation basins, without adding chemicals. Many of the pollutants of concern in CAAP system effluents can be partly or wholly removed with the solids captured in a sedimentation basin. Much of the phosphorus tends to bind with the solids; BOD and organic nitrogen are in the form of organic particles in the fish feces and uneaten feed; and some other compounds, such as oxytetracycline, were found in the sediments captured in sedimentation basins in EPA's sampling data.

Disadvantages of sedimentation basins include the need to clean out accumulated solids, the potential odor emitted from the basin under normal operating conditions, and the inability of the basins to remove small-sized particles without chemical addition. Accumulated solids must be periodically removed and properly disposed of through land application or other sludge disposal methods. For the purpose of costing, EPA assumed no cost associated with the disposal of collected solids in flow-through and recirculating systems. EPA based this assumption on the observation that disposal alternatives are available to CAAP facilities that have a no cost impact. For example, collected solids can be used as a valuable fertilizer by the facility on other facility-owned land or taken for free by local farmers and gardeners. System operators should maintain or increase the efficiency of sedimentation basins by cleaning quiescent zones as frequently as possible and attempt to minimize the breakdown of particles (into smaller sizes) by avoiding cleaning methods that tend to grind up the particles. Industry representatives report that existing CAAP systems might have limited available space for the installation of properly sized sedimentation basins. Therefore, included in the cost for sedimentation basins is a cost for the purchase of land.

9.4.2.2 Design

Settling in sedimentation basins occurs when the horizontal velocity of a particle entering the basin is less than the vertical (settling) velocity in the tank. The settling properties of an effluent, particularly the settling velocities, are determined, and sedimentation basins are sized to accommodate the expected flow through the basin. From Metcalf and Eddy (1991), the length of the sedimentation basin and the detention time can be calculated so that particles with a particular settling velocity (V_c) will settle to the bottom of the basin. The relationship of the settling velocity to the detention time and basin depth is

$$V_c = \text{depth/detention time}$$

Other design factors include the effects of inlet and outlet turbulence, short-circuiting of flows within the basin, solids accumulation in the basin, and velocity gradients caused by disturbances within the basin (such as those from solids removal equipment).

A sedimentation basin does not function if it is frozen. Proper design, construction, and operation of the sedimentation basin are essential for the efficient removal of solids. Collected solids must be removed when they reach the design accumulation depth to ensure the designed removal efficiencies of the sedimentation basin. Otherwise, particles entering the sedimentation basin will not have sufficient depth in which to settle.

For the purpose of cost analysis, EPA assumed the use of quiescent zones (see Section 9.4.1) and offline settling in flow-through systems, which should be less expensive to install and operate than full-flow settling in the larger systems for which requirements are being considered. Large production facilities are not expected to effectively operate full-flow settling basins because of the surface area that would be required to settle the entire volume of water. Offline settling basins in flow-through systems were assumed to treat about 1% of the flow rate in flow-through systems. Thus, full-flow settling would require 100 times more settling capacity than offline settling. In small systems, full flow might be cost-effective in lieu of installing and maintaining quiescent zones (also see IDEQ, n.d.).

EPA used the Computer–Assisted Procedure for the Design and Evaluation of Wastewater Treatment (CAPDET) model (Hydromantis, 2001) to aid in determining capital costs associated with the construction of sedimentation basins. CAPDET is intended to provide planning-level cost estimates to analyze alternative design technologies for wastewater treatment systems (Hydromantis, 2001). CAPDET estimates costs and design parameters based on settling velocity, influent wastewater parameters (TSS in this case), and flow rate. EPA used CAPDET to estimate construction and design (engineering) costs associated with sedimentation basins for both recirculating and flow-through systems. The estimated settling velocity for particles in a CAAP wastewater stream, regardless of system type, ranges from 0.0015 to 0.0030 ft/s, so a mid-range value of 0.0023 ft/s was used (Chen et al., 1994). Chen et al. (1994) provides the most comprehensive review of solids settling for CAAP facilities.

EPA used an average TSS value of 689 mg/L (range of 4 mg/L to 1,040 mg/L from flow-through system sampling data) (Tetra Tech, 2002q, Tetra Tech, 2002r) as the solids input for CAPDET to design the sedimentation basin. For initial costs estimates, EPA used a flow rate of 93.8 gpm, which represented a medium to large flow-through facility. CAPDET cost output was not very sensitive over the range of flow rates from the different model facilities. EPA chose the mid-range value of 93.8 gpm to estimate costs on a dollar per gallon basis to provide more sensitivity in the cost estimates because the flow rates from the model facilities were from a narrow range at the lower end of the input flows used in CAPDET. The value of 93.8 gpm was at about the middle of the range of flows for medium and large flow-through facilities (and at the upper end of the range for recirculating systems). For the range of model facility flows, CAPDET produces a linear relationship between sedimentation basin inflows and cost. Thus, EPA chose the midpoint value of 93.8 gpm to estimate dollars per gallon per minute values to calculate sedimentation basin costs. At 93.8 gpm, CAPDET generates an engineering design cost of $10,300, which is about $109.8/gpm. CAPDET estimates the construction costs at $68,400, or about $729.2/gpm. The construction costs include cost elements for earthwork and concrete work. To determine the design costs for all settling basins, EPA multiplied the flow rate to the settling basin by $109.8; for the construction costs, EPA multiplied the flow rate by $729.2.

EPA estimated land costs by using the settling area calculated by CAPDET and adding 10%. These values were similar to those reported in the Idaho BMP Manual (IDEQ, n.d.) and by Chen et al. (1994). For ease of calculation, land costs were rounded up to the nearest 1%, 10%, 25%, 50%, 75%, or 100% of an acre. EPA used land values of $1,050/ac (USDA, 2000a) and $12,024/ac in Alaska (Alaska Department of Fish and Game, 2002), and the land cost was negligible in the overall cost of implementing settling basins (for large facilities, less than 1% of the total capital cost).

9.4.2.3 Capital Costs: Flow-through Systems

The cost calculation for the design and construction of a sedimentation basin based on the outputs from the CAPDET model are provided below:

Design costs = facility flow rate * 0.01 * $109.8/gpm
Construction costs = facility flow rate * 0.01 * $729.20/gpm

Where:

Facility flow rate = the discharge rate from the facility

EPA included costs for a gravity-fed conveyance system constructed of PVC pipe to carry effluent from each raceway to the sedimentation basin. EPA assumed a quiescent zone configuration similar to that shown in Figure 9.4-1. Quiescent zones have a bottom (floor) drain that connects to a feeder pipe leading to the offline sedimentation basin. EPA assumed that, in the worst case, a series of raceways two wide are placed end to end at a facility. This approach estimates the longest possible length of pipe. The connection from the stand pipe/drain to the feeder pipe is an elbow for all of the raceways in a series. The connection at the feeder pipe is an elbow for the uppermost raceway in a series and a “T” for all other downstream raceways.

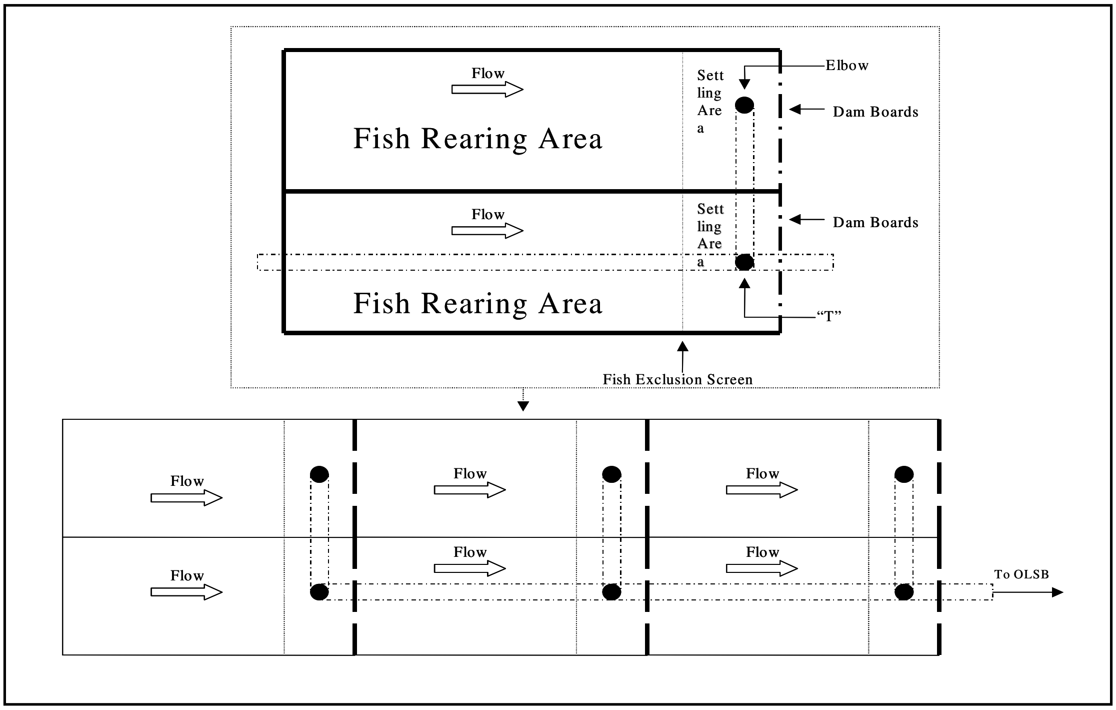


Figure 9.4-1. Model Facility Quiescent Zone Configuration and Drain Layout

EPA assumed 8-in. diameter PVC pipe could be used for all conveyance systems (Hochheimer, 2002). The cost for 8-in. installed PVC pipe was estimated to be $4.25 per linear foot installed underground (VA AG, 2000). The cost for PVC pipe was obtained by multiplying the length of each raceway by the number of raceways (see Section 9.3.1). The costs for 8-in. 90° elbows and "T's" were estimated to be $50.65 and $78.39 each (Hochheimer, 2002). The cost calculation for installation of the conveyance system is as follows:

PVC pipe cost = no. of raceways * raceway length * installed pipe cost

Where:

No. of raceways = the number of production raceways at the model facility
Raceway length = the length of the production raceways at the facility
Installed pipe cost = the price per foot for 8-in. PVC pipe installed

Total cost of "T's" = ((no. of raceways ÷ 2) − 1) * cost per "T"

Where:

No. of raceways = the number of production raceways at the model facility
Cost per "T" = the cost per unit for an 8-in. PVC "T"

Total 90° elbow costs = ((no. of raceways ÷ 2) + 1) * cost per elbow

Where:

No. of raceways = the number of production raceways at the model facility
Cost per elbow = the cost per unit for an 8-in. PVC elbow

Total conveyance system cost = PVC pipe costs + total "T" costs + total elbow costs

After each component was computed, the components were summed to indicate the total capital costs for the sedimentation basin. The calculation for total capital costs is as follows:

Sedimentation basin cost = design cost + construction cost + land cost + conveyance system cost

9.4.2.4 Capital Costs: Recirculating Systems

The construction and design costs for a sedimentation basin at a recirculating facility were also estimated using the CAPDET model. Recirculating systems are expected to generate a maximum of about 10% of the system volume per day, which is about 125,000 gpd in large recirculating systems. The cost calculation for the design and construction of a sedimentation basin is as follows:

Daily discharge rate = total system volume * 0.10

Where:

Total system volume = the total volume of water used for the production of the cultured species

Design costs = daily discharge rate * $109.8/gpm
Construction costs = daily discharge rate * $729.20/gpm

9.4.2.5 Operation and Maintenance Costs: Flow-through and Recirculating Systems

The O&M costs include the labor to maintain and clean the basins. For O&M costs, EPA assumed that no electricity costs would be necessary because the basins operate using gravity flow. CAPDET estimated the time required for general maintenance at 82.7 h/yr for the 93.8-gpm sedimentation basin. This equates to 0.88 h/yr/gpm of flow. EPA used the 0.88 h/yr/gpm, multiplied by the total system flow, to estimate labor requirements. General labor was required for this O&M task, which, as specified by CAPDET, includes checking for proper operation of the sedimentation basin, performing minor repairs, and observing and correcting for short-circuiting of flows.

The O&M costs also include equipment and labor to clean the basin nine times per year. The estimated cleaning frequency was based on information supplied by AAP industry representatives and information obtained during site and sampling visits. EPA assumed that cleaning a settling basin with a front-end loader and a two-person cleaning crew takes 1 day and occurs nine times per year. The cost for renting a front-end loader (tractor) was estimated to be $293.00 per day (RS Means, 2000). For estimating costs, EPA assumed facilities that currently collect solids (facilities with quiescent zones and/or sedimentation basins in place) currently incur the cost of cleaning the sedimentation basins. For those facilities that are not currently collecting solids (those facilities that need to install quiescent zones and sedimentation basins), a front-end loader is not available onsite and one would be rented. The cleaning labor cost associated with cleaning was estimated using the following equation:

Cleaning labor cost = 16 h (2 people, 1 day) * general labor rate

Where:

General labor rate = the hourly wage rate for general labor employees

The total cleaning cost for a sedimentation basin includes the cleaning labor cost plus the cost for the tractor rental. The total cleaning cost was computed as follows:

Total cleaning cost = (tractor rental + cleaning labor costs) * 9 cleanings per year

Where:

Tractor rental = the cost for a 1-day rental of a tractor equipped with a front-end loader

9.4.3 Solids Control BMP Plan

Solids control BMP plans are considered as a management practice for all CAAP facilities under Option 1. All requirements and costs associated with the solids control BMP plans are assumed to be equal for all species and culture systems.

9.4.3.1 Description of Technology or Practice

Evaluating and planning site-specific activities to control the release of solids from CAAP facilities is a practice currently required in several EPA regions as part of individual and general National Pollutant Discharge Elimination System (NPDES) permits (e.g., shrimp pond facilities in Texas, net pens in Maine, and flow-through facilities in Washington and Idaho). BMP plans in these permits require the facility operators to develop a management plan for preventing excess feed from entering the system and removing solids from the effluent. The BMP plan also ensures planning for proper O&M of equipment, especially treatment control technologies. Implementation of the BMP plan results in a series of pollution prevention activities, such as ensuring that employees do not waste feed and planning for the implementation of other O&M activities, which are costed under each technology control or BMP.

9.4.3.2 Capital Costs: All System Types

The capital costs for the BMP plan are based on the amount of managerial time required to develop a plan. The following components should be included in the plan:

- Operational components such as a description of pollution control equipment, feeding methods, preventative maintenance, and the layout and design of the facility.
- Integrated loss control plan to describe precautions taken by the facility to prevent the loss of nonnative species.

- Description of cleaning of culture tanks/raceways and other equipment including how accumulated solids are removed and methods of disposal.
- Description of training for facility personnel to assure they understand the goals and objectives of BMPs and their role in complying with the goals and objectives of the BMP plan.
- Description of records maintenance for feed records, water quality monitoring and final disposition of collected solids.
- The BMP plan should also include a statement that the plan has been reviewed and endorsed by the facility manager and the individuals responsible for the implementation of the plan.

AAP industry representatives (Fromm and Hill, 2002; MacMillan, 2002, personal communication) indicated that development of a solids management BMP plan would take from about 4 hours for smaller facilities to at least 40 hours for larger facilities. Because the proposed requirements for the solids control BMP plan affect medium and large facilities, EPA has assumed that about 40 hours would be required to develop a solids control BMP plan. EPA assumed that the plan would be developed by the facility manager and would be revised or updated as needed or at least every 5 years upon permit renewal. The cost equation for plan development was as follows:

BMP plan costs = 40 h * managerial labor rate

where BMP plan costs are in dollars and the managerial labor rate is $13.46/h ($21.38/h in Alaska).

9.4.3.3 Operation and Maintenance Costs: All System Types

The O&M costs associated with the BMP plan included monthly plan review of 1 h each for the farm manager and one general labor employee. EPA used the following formula to calculate costs associated with this monthly plan review:

BMP O&M costs = [(1 * general labor rate) + (1 * managerial labor rate)]* 12 mo/yr

where O&M costs are in dollars, the general labor rate is $7.69/h ($15.03/h in Alaska), and the managerial labor rate is $13.46/h (21.38/h in Alaska). Other implementation costs are included in the cost of specific unit technologies, such as the costs associated with maintaining quiescent zones.

9.4.4 Compliance Monitoring

For the purpose of estimating costs, EPA assumed compliance monitoring for CAAP facilities was a function of the production level or the production system used at the facility.

9.4.4.1 Flow-through Facilities

EPA estimated the cost of monitoring for flow-through facilities based on the production level (medium or large) at the facility. EPA assumed that all costs related to compliance monitoring would be included under O&M costs. The O&M costs for monitoring consist of two components: (1) the labor associated with sampling (e.g., collecting the sample and preparing it for transport) and transport of the sample to the lab and (2) sampling materials (e.g., bottles) and analysis. EPA estimated for costing purposes that medium facilities, those producing between 100,000 lb and 474,999 lb, monitor weekly for TSS.

EPA estimated costs for the sampling and the transport of the samples to the analysis laboratory at 4 h of general labor, which includes time to collect an 8-h composite sample at 15 min/h to grab one sample per hour and 2 h to prepare the samples and transport them to a lab. Sampling materials and sample analysis were estimated to cost $40.00 per sample, which includes sample bottles (two needed at $2 each), the analysis (at $30/sample), and a cooler with ice (at $6/sample). The total monthly cost for sampling once per month (which includes all the materials, labor for collecting the samples, and the analysis) is estimated to be $283.04 per month, which is added to O&M costs.

EPA estimated monitoring requirements for flow-through facilities producing 475,000 lb or more per year to include both TSS and total phosphorus monitoring at a frequency of once per month. Regulatory Option 1 for the large facilities estimates weekly monitoring for TSS (see costs listed previously).

Regulatory Option 3 also estimates weekly monitoring for total phosphorus, which requires additional weekly sampling materials and an analysis cost of $40 per sample. The cost breakdown is the same as that for TSS. The total monthly cost for sampling (which includes all materials, labor for collecting the sample, and the analysis) was estimated to be $443.04.

9.4.4.2 Recirculating Systems

The monitoring estimates for recirculating CAAP systems are the same as those for flow-through facilities producing 475,000 lb or more per year. EPA assumed that no capital costs would be associated with compliance monitoring for recirculating systems.

9.4.4.3 Operation and Maintenance Costs: Recirculating Systems

The O&M costs for monitoring consist of two components: (1) the labor associated with sampling (e.g., collecting the sample and preparing it for transport) and transport of the sample to the lab and (2) sampling materials (e.g., bottles) and analysis. Monitoring cost estimates are specific to the size of the facility. Recirculating facilities were estimated to monitor weekly for TSS and total phosphorus.

EPA based the monitoring estimates for recirculating systems on the regulatory option chosen. Regulatory Option 1 requires weekly monitoring for TSS (see costs listed previously for flow-through facilities).

Regulatory Option 3 also estimates weekly monitoring for total phosphorus, which requires additional weekly sampling materials and an analysis cost of $40 per sample. The cost breakdown is the same as that for TSS. The total monthly cost for sampling (which includes all materials, labor for collecting the samples, and the analysis) was estimated to be $443.04.

9.4.5 Feed Management

Feed management is a management practice that was considered as part of Option 1 for all net pen operations, but was not required in the proposed regulation.

9.4.5.1 Description of Technology or Practice

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

An advantage of this practice is that proper feed management decreases the costs associated with the use of excess feed that is never consumed by the cultured species. Excess feed distributed to net pens breaks down, and some of the resulting products remain dissolved in the receiving water. More important, solids from the excess feed usually settle and are naturally processed along with feces from the aquatic animals. Excess feed and feces accumulate under net pens, and if there is inadequate flushing this accumulation can overwhelm the natural benthic processes, resulting in increased benthic degradation.

The primary operational factors associated with proper feed management are development of precise feeding regimes based on the weight of the cultured species and constant observation of feeding activities to ensure that the feed offered is consumed. Other feed management practices include use of high-quality feeds, proper storage and handling (which includes keeping feed in cool, dry places; protecting feed from rodents and mold conditions; and handling feed gently to prevent breakage of the pellets), and feeding pellets of proper size. Feed management is a practice required in net pen facility permits issued by EPA Regions 1 and 10 (USEPA, 2002b; USEPA, 2002c).

9.4.5.2 Capital Costs: Net Pens

Because feed management does not require any capital improvements or additions to implement the practice, EPA assumed that no capital costs would be associated with the implementation of feed management for net pen systems.

9.4.5.3 Operation and Maintenance Costs: Net Pens

Observing feeding and keeping records helps net pen system operators to minimize wasted feed and adjust feeding rates as necessary. EPA estimated that implementing a feed management program at a net pen facility would require an extra 10 minutes per net pen for each day of feeding. The extra time required would be used to observe feeding behavior and perform additional record keeping (amount of feed added to each net pen, along with records tracking the number and size of fish in the pen). The record-keeping duties involve filling in a logbook. EPA assumed that feeding occurred once per day, 312 days per year, based on information collected during site visits (Tetra Tech 2002c; Tetra Tech 2002s). EPA assumed that the feed management (observing feeding behavior and record keeping) would be performed by the person feeding and thus included labor costs for a general laborer. EPA also assumed that the farm manager already estimates the amount of feed needed for each daily feeding and performs other management duties related to feeding. The practice considered would have explicitly required written records to document that the person feeding actually carries out the prescribed daily plan.

The equation used to calculate the labor costs is as follows:

> Feed management costs = number of net pens * (10 min/d ÷ 60 min/h) * general labor rate

where feed management costs are in dollars, the number of net pens is derived based on model facility production (see Section 9.3.4), and the general labor rate is $7.69/h.

9.4.6 Drug and Chemical Management

The drug and chemical BMP plan proposed under Option 2 is for large flow-through systems (producing 475,000 lb or more annually), net pens, and recirculating systems. All requirements and costs associated with the drug and chemical BMP plan are estimated to be equal for all species and culture systems.

9.4.6.1 Description of Technology or Practice

The purpose of the proposed drug and chemical BMP plan is to document the use of specific classes of drugs and chemicals, the release of nonnative species, and specific aquatic animal pathogens in the production facility. The plan would also address practices that minimize the inadvertent spillage or release of drugs and chemicals. Additionally, the intentional release of nonnative aquatic animals would be prohibited. Facilities would need to develop an integrated loss control plan before moving or transferring nonnative animals to the facility. The loss control plan should have a schedule for maintenance and inspection of a containment system (screens over inlet and outlet pipes or double nets on net pens). Components of the plan should also include:

- Methods of predator determent
- Escape recovery protocols
- Storm preparedness measures
- Fish transfer procedures

9.4.6.2 Capital Costs: All Systems

The capital costs for the drug and chemical BMP plan include the managerial time required to develop a plan. EPA assumed the facility manager would develop the plan. For estimating costs, EPA assumed the development of the drug and chemical BMP plan would require the same amount of effort as the solids control BMP plan. Development of both plans requires the manager to assess activities at the facility and to develop a written management plan. The plan would require 40 h to complete and would be reviewed, and revised if necessary, every 5 years upon permit renewal. The cost equation for plan development was as follows:

> Drug and chemical BMP plan costs = 40 h * managerial labor rate

where drug and chemical BMP plan costs are in dollars and managerial labor rates are $13.46/h ($21.38/h in Alaska).

9.4.6.3 Operation and Maintenance Costs: All Systems

The O&M costs for the drug and chemical BMP plan include managerial and general labor for meeting and updating the plan.

The O&M costs associated with the drugs and chemical BMP plan include monthly plan review for the farm manager and one general labor employee. EPA used the following formula to calculate costs associated with this monthly plan review:

> Drug and chemical BMP O&M costs = (1 * general labor rate) + (1 * managerial labor rate) * 12 mo/yr

where O&M costs are in dollars, the general labor rate is $7.69/h ($15.03/h in Alaska), and the managerial labor rate is $13.46/h ($21.38/h in Alaska).

9.4.7 Additional Solids Removal (Solids Polishing)

Additional solids removal is considered under Option 3 for flow-through systems and recirculating systems.

9.4.7.1 Description of Technology or Practice

"Solids polishing" refers to the use of a wastewater treatment technology to further reduce solids discharged from sedimentation basins used to treat flow-through and recirculating systems. Several technologies are available, including microscreen filters and polishing ponds. For the purpose of cost analysis, EPA assumed that polishing ponds could be used, especially if particle sizes remain larger than 100 µm. However, for particles 75 to 100 µm, technologies such as microscreens might perform better (Chen et al., 1994). Also, microscreen filters, sized to polish effluents, are available at a much lower cost than that for large solids retention ponds. For example, the cost of a second sedimentation basin for a large salmon flow-through system is up to 100 times the cost of a microscreen filter.

Microscreen filters consist of fine mesh filters that are usually fitted to a rotating drum. The wastewater stream is pumped into the drum, and solids are removed from the effluent as the water passes through the screen. The screen size usually varies from 60 to 90 microns. The filters are equipped with automatic backwash systems that remove collected solids from the screen and direct them to further treatment or solids storage (Chen et al., 1994).

9.4.7.2 Design

EPA assumed that a rotary microscreen filter would be used so that clogging problems were minimized. A small motor rotates the screen to enhance performance, and automatic backwash jets are activated when the pressure drop across the screen reaches a set level (Chen et al., 1994). The backwash solids and water are usually conveyed to a solids storage tank or basin to await proper disposal. Commercial units are readily available for the flow rates and TSS concentrations expected from sedimentation basins at CAAP facilities.

9.4.7.3 Capital Costs: Flow-through and Recirculating Systems

The capital costs for a microscreen filter are based on treating the effluent flow from the settling basin or 1% of the total facility flow. The sizing of the microscreen filter is based on a single unit with the capacity to treat up to 150 gpm. For flows in excess of 150 gpm, EPA costed a larger unit that can treat up to 300 gpm. EPA obtained quotes from vendors of microscreen filters that market to CAAP facilities. The vendors quoted estimated costs of $7,527.50 for the smaller unit and $8,049.45 for the larger unit. The costs for shipping and delivery were estimated to be $200 (Chen et al., 1994).

Microscreen filters are relatively small (with a footprint of about 25 ft^2) and can be installed adjacent to the sedimentation basin. EPA observed that most of the larger facilities had electrical service readily available around the facility. For the purpose of estimating costs, EPA assumed the filter would be installed within 40 feet of the previous treatment technology at the facility and within 100 feet of the closest electrical connection. The filters contain electrical motors that can be powered by a standard GFI electrical outlet. The costs for each component of the electrical installation are included in Table 9.4-1.

Table 9.4-1. Installation Costs

Component	*Unit Costs*	*Total Costs*
# 8 Stranded copper wire	$15.60/100 ft	$46.80
Wire installation	$50.90/100 ft	$50.90
Wire conduit	$7.30/100 ft	$7.30
Trencher	$19.91/h	$19.91
GFI receptacle (installed)	$74.50	$74.50
6-inch PVC pipe (installed)	$3.15/ft	$126.00

Source: RS Means, 2000.

9.4.7.4 Operation and Maintenance Costs: Flow-Through and Recirculating Systems

For the purpose of estimating costs, EPA assumed O&M for the microscreen filter would take 5 min/d of general labor on 312 d/yr for general maintenance and to ensure the filter was functioning properly (Chen et al., 1994). EPA assumed most flow-through facilities operate minimal crews 1 d/wk, but the filter operates 24 h/d, 365 d/yr. The cost calculation for general labor was as follows:

General labor costs = 5 min/d ÷ 60 min/h * 312 d/yr * general labor rate

where the general labor costs were in dollars and the general labor rate was $7.69/h ($15.03/h in Alaska).

EPA assumed the electricity requirements for the microscreen filter would be 12,900 kWh/yr (Chen et al., 1994). The national average electricity costs were found to be $ 0.07/kWh (EIA, 2002), or $0.08/kWh in Alaska. The total electricity costs for the microscreen filter were computed using the following equation:

Electricity costs = electricity requirement (kWh) * electricity costs per kWh

AAP industry representatives indicated that the microscreen should be replaced approximately every 2 yr under normal conditions (Chen et al., 1994). The cost for a new microscreen was estimated at $500 (Chen et al., 1994). The cost for a new screen was divided over 2 yr of O&M costs, resulting in a yearly cost of $250.

9.4.8 Active Feed Monitoring

Active feed monitoring is considered as a management practice in Option 3 for all net pen facilities. Active feed monitoring is a relatively new but proven technology used by some facility operators in the salmon industry. Some type of remote monitoring equipment, such as an underwater video camera, is lowered from the surface to the bottom of a net pen during feeding to monitor for uneaten feed pellets as they pass by the video camera.

9.4.8.1 Description of Technology or Practice

The goal of active feed monitoring is to further reduce pollutant loads associated with feeding activities. A variety of technologies have been reported, including video cameras with human or computer interfaces to detect passing feed pellets. A new NPDES permit issued in Maine (USEPA, 2002b) also suggests that ultrasonic equipment might be available. Most facilities that use this technology use a video monitor at the surface that is connected to the video camera. An employee watches the monitor for feed pellets passing by the video camera and then stops feeding activity when a predetermined number of pellets (typically only two or three) pass the camera.

9.4.8.2 Capital Costs

The camera equipment includes a single portable underwater video camera and a monitor for a facility, estimated to cost about $10,000, with a life span of greater than 10 years (Tetra Tech, 2002c; Tetra Tech, 2002s). EPA observed the use of portable feed monitoring equipment, which consists of the monitor mounted on a wheeled cart that is pushed from pen to pen along the floating walkway and the camera mounted on a long cable that is dropped into the pen being monitored. The camera and monitor was easily moved from pen to pen (Tetra Tech, 2002c; Tetra Tech, 2002s).

9.4.8.3 Operation and Maintenance Costs

For O&M costs, EPA assumed that an active feed monitoring system would require an additional 10 min of general labor per net per feeding day. EPA assumed that feeding would take place 6 d/wk or 312 d/yr. The equation used to calculate the additional general labor cost is as follows:

General labor cost = (10 min ÷ 60 min/h) * no. of net pens * 312 d/yr * labor rate

Where:

- General labor cost is the labor cost in dollars
- Number of net pens is calculated in Section 9.3.4
- 312 d/yr assumes feeding takes place 6 d/wk
- The general labor rate is $7.69/hr

9.5 FREQUENCY FACTORS

Applying the frequency factors to the unit component costs reduces the effective cost of that component for the model facility. Essentially, EPA adjusts the component cost to account for those facilities that already have the component in place. Facilities that already have the component in place would not have to install and operate a new component as a result of the proposed regulation. If a cost component has a frequency factor value of zero, the cost for that component is incurred by all facilities. If a cost component has a frequency factor of 1, the cost for that component is incurred by none of the facilities.

EPA estimated frequency factors based on sources such as those listed below. (Each source was considered along with its limitations.)

- EPA site visit information was used to assess general practices of CAAP facility operations and how they vary among regions and size classes.
- The screener survey was used to assess general treatment practices, determine specific frequency factors of CAAP facility operations, and evaluate variation of treatments among regions and size classes.
- EPA used observations on CAAP operations by industry experts, who were contacted to provide insight into operations and practices, especially where data were limited or not publicly available.
- The data currently available from the NASS 1998 CAAP Census were used to determine the distribution of CAAP facility operations across the USDA Regional Aquaculture Center regions by size class.
- *State Compendium: Programs and Regulatory Activities Related to Aquatic Animal Production* (Hochheimer and Mosso, 2002) was used to estimate frequency factors, based on current requirements for treatment technologies and BMPs that already apply to CAAP facilities in various states. For example, BMP plans are required for all facilities with permits in Idaho and Washington, so the facilities in these states were assumed to have solids control BMP plans in place.

9.5.1 Quiescent Zones

Quiescent zones are commonly used by flow-through CAAP facilities to remove solids. EPA developed frequency factors for quiescent zones in flow-through CAAP facilities from the AAP screener survey (Westat, 2002), and they are presented in Table 9.5-1.

Table 9.5-1. Quiescent Zone Frequency Factors

Species	*Model*	*Frequency Factor*
Trout-Food-size-Commercial-Flow-through	Medium	0.91
	Large	1.00
Trout-Food-size-State-Flow-through	Medium	1.00
	Large	1.00
Trout-Stockers-Commercial-Flow-through	Medium	1.00
Trout-Stockers-Federal-Flow-through	Medium	0.57

Species	Model	Frequency Factor
	Large	0.50
Trout-Stockers-State-Flow-through	Medium	0.91
	Large	1.00
Trout-Stockers-Other-Flow-through	Medium	1.00
	Large	1.00
Tilapia-Commercial-Flow-through	Medium	0.67
	Large	1.00
Tilapia-Commercial-Recirculating	Large	—
Striped Bass-Commercial-Flow-through	Medium	1.00
Striped Bass-Commercial-Recirculating	Large	—
Salmon-Other-Flow-through	Large	1.00

9.5.2 Sedimentation Basin

Sedimentation basins are the most common solids separation technique used to treat effluents in the United States. EPA based frequency factors for sedimentation basins used in the cost model for flow-through and recirculating CAAP facilities on the AAP screener survey (Westat, 2002), and they are presented in Table 9.5-2.

Table 9.5-2. Sedimentation Basin Frequency Factors

Species	Model	Frequency Factor
Trout-Food-size-Commercial-Flow-through	Medium	0.91
	Large	1.00
Trout-Food-size-State-Flow-through	Medium	1.00
	Large	1.00
Trout-Stockers-Commercial-Flow-through	Medium	1.00
Trout-Stockers-Federal-Flow-through	Medium	0.57
	Large	0.50
Trout-Stockers-State-Flow-through	Medium	0.91
	Large	1.00
Trout-Stockers-Other-Flow-through	Medium	1.00
	Large	1.00
Tilapia-Commercial-Flow-through	Medium	0.67
	Large	1.00
Tilapia-Commercial-Recirculating	Large	1.00
Striped Bass-Commercial-Flow-through	Medium	1.00
Striped Bass-Commercial-Recirculating	Large	1.00
Salmon-Other-Flow-through	Large	1.00

9.5.3 BMP Plans

Solids management BMP plans are currently required of CAAP facilities operating in EPA's Region 10 (e.g., Idaho, Oregon, and Washington). EPA developed frequency factors for solids management BMP plans in flow-through, net pen, and recirculating CAAP facilities from the AAP screener survey (Westat, 2002), and they are presented in Table 9.5-3.

Table 9.5-3. BMP Plan Frequency Factors

Species	*Model*	*Frequency Factor*
Trout-Food-size-Commercial-Flow-through	Medium	0.32
	Large	1.00
Trout-Food-size-State-Flow-through	Medium	0.00
	Large	0.00
Trout-Stockers-Commercial-Flow-through	Medium	0.60
Trout-Stockers-Federal-Flow-through	Medium	0.14
	Large	0.50
Trout-Stockers-State-Flow-through	Medium	0.02
	Large	0.00
Trout-Stockers-Other-Flow-through	Medium	1.00
	Large	1.00
Tilapia-Commercial-Flow-through	Medium	0.00
	Large	0.00
Tilapia-Commercial-Recirculating	Large	0.40
Striped Bass-Commercial-Flow-through	Medium	0.00
Striped Bass-Commercial-Recirculating	Large	0.00
Salmon-Other-Flow-through	Large	0.00
Salmon-Commercial-Net Pen	Large	0.13

9.5.4 Feed Management

Feed management is a commonly used practice in the CAAP facility industry because its benefits include both a costs savings for farms and reductions to pollutant loads. Feed management is specified as a management practice for net pen operations. Frequency factors used in the cost model are based on the AAP screener survey (Westat, 2002) and are listed in Table 9.5-4.

Table 9.5-4. Feed Management Frequency Factor

Species	*Model*	*Frequency Factor*
Salmon-Net Pen	Large	0.88

9.5.5 Drug and Chemical BMP Plan

EPA does not currently know of any facilities that have developed a drug and chemical BMP plan. Therefore, for the purpose of estimating costs, EPA assumed the frequency factors for a drug and chemical BMP plan in flow-through, net pen, and recirculating CAAP facilities were all zero.

9.5.6 Solids Polishing

Approximately 5% of all facilities responding to EPA's AAP screener survey (Westat, 2002) reported using several different treatment technologies, including microscreen filters, for additional solids removal. EPA developed frequency factors for additional solids removal in flow-through and recirculating CAAP facilities from the AAP screener survey (Westat, 2002). They are presented in Table 9.5-5.

Table 9.5-5. Solids Polishing Frequency Factors

Species	*Model*	*Frequency Factor*
Trout-Food-size-Commercial-Flow-through	Medium	0.09
	Large	0.00
Trout-Food-size-State-Flow-through	Medium	0.00
	Large	0.00
Trout-Stockers-Commercial-Flow-through	Medium	0.00
Trout-Stockers-Federal-Flow-through	Medium	0.00
	Large	0.00
Trout-Stockers-State-Flow-through	Medium	0.05
	Large	0.00
Trout-Stockers-Other-Flow-through	Medium	0.00
	Large	0.00
Tilapia-Commercial-Flow-through	Medium	0.00
	Large	0.00
Tilapia-Commercial-Recirculating	Large	0.40
Striped Bass-Commercial-Flow-through	Medium	1.00
Striped Bass-Commercial-Recirculating	Large	0.67
Salmon-Other-Flow-through	Large	0.00

9.5.7 Compliance Monitoring

The frequency factor for compliance monitoring was estimated at zero in the absence of any data readily available to EPA linking facilities used to estimate costs in the model facility analysis.

9.5.8 Net Pen Active Feed Monitoring

EPA developed frequency factors for active feed monitoring in net pen CAAP facilities from the AAP screener survey (Westat, 2002). They are presented in Table 9.5-6.

Table 9.5-6. Active Feed Monitoring Frequency Factors

Species	*Model*	*Frequency Factor*
Salmon-Net Pen	Large	0.38

9.6 OUTPUT DATA

EPA combined results from the unit cost modules (Section 9.4) and the frequency factors (Section 9.5) to form the inputs to industry estimated costs. Appendix B provides results for all of the model facilities that EPA analyzed for flow-through, recirculating, and net pen systems. Appendix B includes the analysis for Alaska salmon flow-through facilities. EPA used these results to develop weighted component unit costs and combined the unit costs to form the costs for each model facility. EPA then summed the model facility costs to estimate the total industry costs. This section provides a detailed explanation of the process EPA used to estimate these costs.

9.7 CHANGES TO COSTING METHODOLOGY

9.7.1 Background

While the proposed regulatory options were under development, EPA performed several analyses and reviews to evaluate the options, including sharing drafts with stakeholders, small entity representatives (SERs), and technical experts. As specific elements of the proposed options were defined, EPA researched technical literature and studies and contacted technical experts to better quantify the compliance costs and the pollutant load removal efficiencies of the options. Throughout the option development process, EPA continued to modify the options to reflect new information as it became available. EPA developed and presented (to the Small Business Regulatory Enforcement Fairness Act (SBREFA) panel) a range of control technology and BMP options and estimated their compliance costs as part of the small business panel process.

EPA considered several technology options in its initial analysis. Some of these options were estimated to require a high cost in relation to revenues, and therefore EPA did not pursue those technologies further. For example, one option EPA considered, but did not pursue, was disinfection. EPA considered disinfection as an option to control pathogens present in effluents from solids collection and storage units at AAP facilities, which might adversely affect human health. The economic impact of the estimated costs for disinfection was found to be high in proportion to revenues and could impose a severe adverse economic impact on facilities required to implement disinfection.

Initially, EPA also considered a feed management BMP plan for all subcategories. Based on input from industry representatives, EPA removed this option component for all subcategories except net pen systems. SERs indicated that good feed management practices are site-specific for individual facilities and are already a common practice throughout the AAP industry. Industry input also indicated that facilities apply good feed management practices as an effective animal husbandry measure, as well as a means of keeping facility costs down. Although EPA is still applying feed conversion ratio data in the cost and loadings models to estimate pollutant loadings in the raw waste, the Agency is not assigning a specific FCR as a goal to represent optimum feed management.

EPA performed several analyses, including economic and technical analyses, to evaluate the impacts of the proposed regulation on various sectors of the CAAP industry. As a result of the economic analyses, consultation with industry experts, and the deliberation of the Small Business Advisory Review Panel, production of aquatic animals in pond systems, lobster pounds, and aquariums, as well as the production of crawfish, molluscan shellfish in open waters, and alligators were no longer considered within the scope of the proposed regulation. This section will summarize the analysis of these system types and the development of options and their costs, but does not provide the same level of detail as prescribed earlier for systems subject to the proposed requirements.

9.7.1.1 Pond Systems

EPA considered numerous management practices for pond operations, such as discharge management technologies. After extensive discussions with industry experts, the Agency concluded that discharge management technologies would provide limited benefits in reducing wastewater pollutants discharged during pond drainage for most aquatic animals species grown in pond systems.

9.7.1.2 Lobster Pounds

Intertidal "pounds" are used for live storage of marine crustaceans (e.g., lobsters, crabs) to keep caught wild animals alive pending sale. EPA is not proposing nationally applicable effluent limitations guidelines for lobster pounds at this time because the Agency has not found any applicable pollutant control technologies to reduce discharges. EPA continues to evaluate BMPs that might apply for these types of facilities.

9.7.1.3 Crawfish

Crawfish are typically raised in conjunction with plant crops, such as rice or soybeans, because crawfish maintain aeration of the growing medium. EPA is not proposing nationally applicable effluent limitations guidelines for discharges associated with crawfish operations because crawfish producers do not add feed, drugs, or chemicals to manage the crawfish operations and because any associated pollutants tend to be assimilated into the soils used to grow plant crops.

9.7.1.4 Molluscan Shellfish Production in Open Waters

For large-scale production of molluscs for food, operators typically use bottom culture, bottom- anchored racks, or floating rafts tethered to the bottom in open waters. Because such operations do not typically add materials to waters of the United States, and because EPA has not found any generally applicable pollutant control technologies to reduce any discharge, the Agency is not proposing effluent limitations guidelines and standards for discharges from open-water mollusc culture. EPA notes that molluscs are filter feeders that in some cases are recommended not only as a food source but also as a pollution control technology. Molluscs remove pollutants from ambient waters by filtration. EPA also is aware that molluscs have been incorporated into polyculture AAP operations to minimize discharges of pollutants.

9.7.1.5 Aquariums

Public aquariums are AAP facilities that display a variety of aquatic animals to the public and conduct research on many different threatened and endangered aquatic species. EPA has determined, through the AAP screener survey, that most aquariums are indirect dischargers. If these facilities discharge directly into waters of the United States, it is done only in emergency situations requiring rapid tank dewatering. These systems maintain low stocking densities and very clean, clear water to enhance the visual display of the animals. Discharges from aquariums are likely to be low in TSS and nutrients because of the low stocking densities. Because most of the drugs used to treat stressed or ill animals are injected directly into the animal, EPA believes that discharges of drugs would be minimal. The few chemicals used include pH buffers and chemicals used to make artificial sea salt.

9.7.1.6 Alligators

Alligator production systems are unique because they produce discharges from production units in "batches" when pens or huts are drained and cleaned. EPA found that effluents from alligator production systems are typically treated and stored on-site in lagoons. After consultation with industry representatives, EPA also discovered that alligator production facilities do not discharge from treatment lagoons. Excess volume in lagoons is applied to cropland.

9.7.2 Modifications to Model Facility Methodology

EPA developed model facilities to reflect CAAP facilities with a specific production system, type of ownership, and often species. These model facilities were based on data gathered during site visits, information provided by industry members and their associations, and other publicly available information. EPA estimated the number of facilities represented by each model using data from the AAP screener survey (Westat, 2002), in conjunction with information from the USDA 1998 Census of Aquaculture (USDA, 2000b). EPA estimated costs for each model facility and then calculated industry-level costs by multiplying model facility costs by the estimated number of facilities required to implement the treatment technology or management practice in each model category.

Initially, EPA developed the production rate thresholds based on data from the 1998 Census of Aquaculture (USDA, 2000b). To group the facility production data reported in the screener surveys (Westat, 2002), EPA used six production size categories, based on revenue classifications in the 1998 Census of Agriculture: $1,000 to $24,999; $25,000 to $49,999; $50,000 to $99,999; $100,000 to $499,999; $500,000 to $1,000,000; and >$1,000,000. EPA used national average product prices, taken from the 1998 Census, to estimate the production (in pounds) for the dominant species that were reported grown in ponds (e.g., catfish, hybrid striped bass, shrimp), flow-through (e.g., trout salmon, tilapia), recirculating (e.g., tilapia, hybrid striped bass), and net pen (e.g., salmon) systems. For alligator systems reported in the screener survey, EPA used data from industry reports to estimate production value and create groupings of the facilities. EPA used this size classification grouping to more accurately estimate costs of the proposed limitations and standards for each of the size classifications within the various species (or aquatic animal types) cultured in this industry. That is, instead of assuming one model facility for each of the three regulatory subcategories, EPA used a minimum of six model facilities for each facility type (e.g., commercial, government, research, tribal) and species size combination (e.g., fingerlings, stockers, food-size) for better accuracy in its analyses. EPA applied these size classifications to the screener survey data to derive the model facility characteristics that have been used to support the proposed regulation. Final cost estimations for the proposed options are based on screener survey data. Commercial facilities are adjusted by a scaling factor, which is the ratio of commercial facilities in the 1998 Census of Aquaculture to the number of commercial facilities responding to the AAP screener survey.

Several SERs (Engle, 2002; Hart, 2002; Pierce, 2002; Vaught, 2002) questioned the ability of a model facility to capture the diversity of production sizes and operational differences among AAP facilities. EPA used average production data and average values to estimate loadings to account for some of the variation among facilities. EPA recognizes the diversity in the AAP industry; however, the Agency does not have site-specific data on each AAP facility. EPA used the best available data to make its estimates for the cost models, including AAP screener survey results, USDA Census of Aquaculture data, and technical input from producers and industry leaders. These data sources will be supplemented with the results of EPA's detailed survey in the final rule.

9.7.3 Pond Systems

Based on additional input from industry representatives regarding in-pond processes, pond systems were evaluated for their unique ability to serve as treatment systems, and this treatment capacity was incorporated into the assessment of various options for ponds (Hargreaves, 2002a, personal communication; Hargreaves, 2002b). EPA considered several factors related to pond systems in this initial option evaluation, including the relationship of draining frequency to pollutants discharged, water management strategies in ponds, and species-specific operational factors. The culture of aquatic animals in ponds requires pond owners to maintain high-quality water at all times to sustain and grow the aquatic animal crop. Most pond owners drain or actively discharge water only when necessary to completely harvest a crop or to maintain the pond. The frequency of draining is usually once per year and associated with harvesting the crop, but it can be less than once per 10 or more years. For many aquatic animals raised in ponds, the pond itself serves as a natural biological treatment system to reduce wastes generated by the animals in the pond (including excess feed, manure, and dead aquatic animals). The only other time a pond might discharge is when excess runoff occurs (usually during periods of heavy precipitation). Most ponds have overflow pipes that drain passively from the top surface of the pond. The water quality of this overflow discharge is comparatively high (Tucker et al., 2002).

Shrimp are produced in ponds, but the operation of shrimp ponds is somewhat different from that of ponds in which other aquatic animals are raised. To harvest shrimp, the pond is drained, and the shrimp are removed from the pond along with the water. Shrimp are captured external to the pond in a harvest box. The water must be drained rapidly from the pond to prevent the shrimp from burrowing into the pond bottom. Because of the need to drain the ponds so rapidly, there is a greater potential for the discharge of pollutants resulting from the disturbance of the pond bottom. Therefore, EPA evaluated shrimp culture in ponds and found ponds to have adequate controls and BMPs in place. Shrimp pond effluents potentially contain higher TSS and BOD loadings than other pond drainage. State requirements for existing shrimp farms include the capture of discharge water in sedimentation basins or constructed wetlands to minimize the release of TSS so that facilities can meet effluent limits set by the state. Some shrimp farmers reuse the water discharged from draining ponds to fill other ponds or to grow other aquatic animal crops (e.g., oysters or clams) over the winter. Most of the shrimp grown in the United States is considered nonnative, which leads to concern regarding escapement of the shrimp and discharge of exotic pathogens when disease outbreaks occur. Strict state requirements are in place to minimize the risk of shrimp escapement and release of pathogens. These requirements include use of certified disease-free seed stock, testing of animals before harvest or draining, BMP plans, and mandatory escapement controls.

9.7.4 Flow-through and Recirculating Systems

EPA initially considered an approach to manage the use of drugs and chemicals, minimize the escape of nonnative species, and maintain animal health similar to the Hazardous Analysis at Critical Control Points (HACCP) paradigm used in the food processing industry. Input from industry representatives indicated that an HACCP-based plan, with its extensive training and record-keeping requirements, would be expensive to implement. The requirement would also depend on the creation of an infrastructure to provide the training necessary to develop and implement these plans. Industry input also indicated that the plan did not have clearly identified targets. Therefore, EPA modified the approach and developed a drug and chemical BMP plan. Under the drug and chemical BMP plan, facilities would develop a plan to prevent spills or accidental discharges.

EPA also proposes to require facilities to develop and implement a BMP plan that addresses the discharge of solids from recirculating and flow-through systems. This plan would include cleaning and maintaining quiescent zones. EPA revised its labor cost estimates for quiescent zone maintenance to reflect input from industry representatives. Input from the industry indicated that most facilities spend approximately 15 to 30 min/wk cleaning quiescent zones. Using the high end of this range (30 min/wk) and the number of days per week for normal facility operations (6 d/wk), EPA reduced its estimate of the time needed to clean quiescent zones from 30 minutes to 5 minutes per raceway per day. EPA considers quiescent zone cleanings part of normal facility operations, and input from industry representatives (Hinshaw, 2002, personal communication; MacMillan, 2002, personal communication) indicates that most facilities conduct normal operations 6 d/wk. EPA also based quiescent zone cleaning on 312 d/yr, which more accurately reflects the 6 d/wk schedule of facilities.

EPA estimated construction and O&M costs on a per gallon treated basis to enable ease of calculations for the different sizes of facilities encountered in the cost modeling. Using this approach, EPA initially estimated costs over a wide range of facilities, including many in the 20,000 to 50,000-pound size range. Certain fixed costs, such as design and equipment mobilization costs, are relatively constant for construction of sedimentation basins at facilities of any size. EPA used an average treatment volume, which was strongly influenced by the large number of smaller facilities that use flow-through systems, to estimate the initial design volume for scaling costs among all model facilities. For example, construction costs for sedimentation basins were reduced from $0.014 per gallon treated to $0.0014 per gallon treated by increasing the average sedimentation basin size up to 93.8 gpm. This cost reduction reflects EPA's reevaluation of sizing and costs for larger-sized sedimentation basins that would be needed at the medium- and large-sized flow-through and recirculating facilities. EPA analyzed the CAPDET (Hydromantis, 2001) capital and O&M cost estimates for facilities in the medium and large size range and found the costs to be linear over this range of system sizes. When looking at smaller sizes, however, the costs were not linear. Design costs for sedimentation basins were also reduced from $0.0021 per gallon treated to $0.000209 per gallon treated. Values for O&M labor for sedimentation basins has been reduced from

$0.000008 per gallon treated to $0.0000017 per gallon treated. (See Section 9.4 for additional information on sizing of sedimentation basins.)

Although EPA initially considered disinfection treatment as a regulatory option, it is not being considered for the proposed regulation. After reviewing existing NPDES permits and consulting with industry experts and EPA regional NPDES coordinators, EPA believed that practices like disinfection would not be affordable and that the supporting data were too inconclusive to warrant disinfection as a treatment option. (An analysis of the microbiological indicator data collected at the sampled facilities did not clearly indicate the presence of human health pathogens.)

Another modification to the cost model includes the cost components for compliance monitoring in Options 1 and 3 to reflect the monitoring that would be necessary to comply with the numeric limits for TSS.

9.7.5 Net Pen Systems

Net pen systems are unique because their placement directly in the receiving water allows little opportunity for the treatment of effluents. Initially EPA targeted management practices that reduce feed inputs and uneaten feed in the development of options for net pen systems. After consulting with industry representatives and evaluating AAP screener survey data and existing NPDES permits, EPA found some net pen facilities currently using feed management practices. Thus, EPA determined the estimated cost of implementing feed management to be affordable.

Initially EPA also considered an option requiring net pen facilities to develop HACCP plans. Input from industry representatives indicated that an HACCP-based plan, with its extensive training requirements, would not be affordable to implement. Comments from industry representatives indicated that EPA's estimates of costs associated with training and hours needed for developing the HACCP-based plan were too low. Industry input also indicated that the plan did not have clearly identified targets. EPA evaluated current industry practices and found that some of the facilities with NPDES permits are required to have loss control plans and implement practices (such as double netting and inventory reporting) to prevent escapes. The original BMP plan, now the drug and chemical BMP plan, requires only BMPs for pathogen control, prevention of nonnative species escapement, and reporting requirements for drugs and chemicals.

EPA evaluated the labor costs for mortality removal in the cost calculations and found that mortality removal is an integral part of daily net pen system management. Input from site visits confirmed that facilities already routinely remove mortalities and take them to land-based disposal sites.

EPA changed the feed management BMP plan to a broader solids management plan, which requires the facility to develop and implement a plan to reduce treatment of solids discharged. EPA found this required in several states and regional NPDES permits. EPA used a lower FCR as a means to measure the removal efficiency of each pollutant based on the effectiveness of the solids management BMP plan.

9.8 References

Alaska Department of Fish and Game. 2002. *Senate Bill 183 Restoration and Land Acquisitions*. Alaska Department of Fish and Game, Habitat and Restoration Division. <http://www.state.ak.us/adfg/habitat/geninfo/specialprojects/sb183.htm>. Accessed June 2002.

Alaska Department of Labor and Workforce Development. 2002. *2000 Alaska Wage Rates: Statewide*. Alaska Department of Labor and Workforce Development, Research and Analysis Section. <http://www.labor.state.ak.us/research/wage/swoes.htm>. Accessed May 2002.

Chen, S., D. Stechey, and R.F. Malone. 1994. Suspended Solids Control in Recirculating Aquaculture Systems. In *Aquaculture Water Reuse Systems: Engineering Design and Management*, ed. M.B. Timmons and T.M. Losordo, pp. 61-100. Elsevier, Amsterdam, The Netherlands.

Chen, S., S. Summerfelt, T. Losordo, and R. Malone. 2002. Recirculating Systems, Effluents and Treatments. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 119-140. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Department of Labor, Bureau of Labor Statistics. 2001. *Current Population Survey Data*. Table 19 Persons at Work in Agriculture and Nonagricultural Industries by Hours of Work and Table 39 Median Weekly Earnings of Full-Time Wage and Salary Workers by Detailed Occupation and Sex. <http://www.Stats.bls.gov/cps/>.

EIA (Energy Information Administration). 2002. *Retail Sales of Electricity, Revenue, and Average Revenue per Kilowatt-hour (and RSEs) by United States Electric Utilities to Ultimate Consumers by Census Division, and State, 2000 and 1999—Commercial*. U.S. Department of Energy, Energy Information Administration, Washington, DC. <http://www.eia.doe.gov/cneaf/electricity/epav1/ta23pl.html>. Accessed January 2002.

Engle. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Fromm, C.H., and H.B. Hill. 2002. Technical memorandum to record. Janet Goodwin, U.S. Environmental Protection Agency. Seattle, WA.

Hargreaves, J., 2002a. Mississippi State University. Personal communication (Monte Carlo simulation), February 2002.

Hargreaves J., 2002b. Mississippi State University. Memo (Monte Carlo simulation), February 2002.

Hart. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source

Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Hinshaw, J., 2002. North Carolina State University. Personal communication, February 20, 2002.

Hinshaw, J., and G. Fornshell. 2002. Effluents from Raceways. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 77-104. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Hochheimer, J. 2002. Technical Memorandum: Description of Trout Model Facility Calculations. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and C. Moore. 2002. Technical Memorandum: Development of Model Facilities. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and D. Mosso. 2002. Technical Memorandum: Summary of Aquatic Animal Production Industry Permits and Regulations. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and H. Westers. 2002a. Technical Memorandum: Fish Growth, Feed Conversion, and Waste Production in Aquaculture. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and H. Westers. 2002b. Technical Memorandum: Flow-Through Systems. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and H. Westers. 2002c. Technical Memorandum: Water Sources, Uses and Conservation Measures in Aquaculture. Tetra Tech, Inc., Fairfax, VA.

Hydromantis, Inc. 2001. *CAPDET: For the Design and Cost Estimation of Wastewater Treatment Plants Version 1.0*. [Computer program and manual]. Hydromantis, Inc. Consulting Engineers, Ontario, Canada.

IDEQ (Idaho Department of Environmental Quality). n.d. *Waste Management Guidelines for Aquaculture Operations.* Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

Jackoviac, J. 2002. Harietta Hatchery, Harietta, MI. Personal communication, March 4, 2002.

MacMillan, J. 2002. Clear Springs Foods, Buhl, ID. Personal communication, March 4, 2002.

McNair, M. 2001. *Alaska Salmon Enhancement Program: 2000 Annual Report*. Regional Information Report no. 5J01-01. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, AK.

Metcalf and Eddy, Inc. 1991. *Wastewater Engineering: Treatment and Disposal*, 3d ed. revised by G. Tchobanoglous and F. Burton. pp. 220-240. McGraw Hill, NY.

Pierce. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source

Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Plemmons. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

RS Means. 2000. *RS Means Building Construction Cost Data*. 58th annual edition, ed. P.R. Waier, R.S. Means Company, Inc. Kingston, MA.

Rheault. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Rice. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Sumerfelt, S.T., J. Davidson, and M.B. Timmons. 2000. Hydrodynamics in the “Cornell-Type” Dual-Drain Tank. In: *Proceedings of the 2000 International Conference on Recirculating Aquaculture*, Blacksburg, VA.

Swanson, J. 2002. Tetra Tech, Inc., Fairfax, VA. Personal communication, January 15, 2002.

Tetra Tech, Inc. 2002a. Alaska salmon conference call summary, February 2002.

Tetra Tech, Inc. 2002b, August. Site visit report for MinAqua Fisheries Facility, Renville, MN.

Tetra Tech, Inc. 2002c, August. Site visit report for Heritage Salmon, Eastport, ME.

Tetra Tech, Inc. 2002d, August. Site visit report for Harrietta Hatchery, Harrietta, MI.

Tetra Tech, Inc. 2002e, August. Site visit report for Platte River Hatchery, Beulah, MI.

Tetra Tech, Inc. 2002f, August. Site visit report for Rushing Waters Fisheries, Palmyra, WI.

Tetra Tech, Inc. 2002g, August. Site visit report for Embden Rearing Station and Governor Hill Hatchery, Augusta, ME.

Tetra Tech, Inc. 2002h, August. Site visit report for Green Lake National Fish Hatchery, Ellsworth, ME.

Tetra Tech, Inc. 2002i, August. Site visit report for Cantrell Creek Trout Farm, Brevard, NC.

Tetra Tech, Inc. 2002j, August. Site visit report for Sweetwater Trout Farm, Sapphire, NC.

Tetra Tech, Inc. 2002k, August. Site visit report for Clear Springs Foods, Inc. Snake River Facility, Buhl, ID.

Tetra Tech, Inc. 2002l, August. Site visit report for Clear Springs Foods, Inc., Box Canyon Facility, Buhl, ID.

Tetra Tech, Inc. 2002m, August. Site visit report for Pisces Investments, Magic Springs Facility, Twin Falls, ID.

Tetra Tech, Inc. 2002n, August. Site visit report for Bill Jones Facility, Twin Falls, ID.

Tetra Tech, Inc. 2002o, August. Site visit report for Fins Technology, Turner Falls, MA.

Tetra Tech, Inc. 2002p, August. Site visit report for Lake Wheeler Road Agricultural Facility, Raleigh, NC.

Tetra Tech, Inc. 2002q. Sampling Event Report for Harrietta Hatchery, Harrietta, MI.

Tetra Tech, Inc. 2002r. Sampling Event Report for Clear Springs Foods, Inc. Box Canyon Facility, Buhl, ID.

Tetra Tech, Inc. 2002s, August. Site visit report for Acadia Aquaculture, Mt. Desert, ME.

Tucker, C.S., C.E. Boyd, and J.A. Hargreaves. 2002. Characterization and Management of Effluents from Warmwater Aquaculture Ponds. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 35-76. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

USDA (U.S. Department of Agriculture). 2000a. *Agricultural Land Values*. U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), Washington, DC.

USDA (U.S. Department of Agriculture). 2000b. *The 1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agricultural Statistical Services, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002a. *Detailed Questionnaire for the Aquatic Animal Production Industry*. OMB Control No. 2040-0240. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002b. National Pollutant Discharge Elimination System Permit no. ME0036234, issued to Acadia Aquaculture, Inc. Signed February 21, 2002.

USEPA (U.S. Environmental Protection Agency). 2002c. National Pollutant Discharge Elimination System Permit no. WA0040878, issued to Washington State Department of Fish and Wildlife, South Sound Net Pens, Mason County. Signed March 20, 2002.

USEPA (U.S. Environmental Protection Agency). 2002d, August. Site visit report for Virginia Tech Aquaculture Center, Blacksburg, VA.

VA, AG. 2000. USDA/NRCS – Conservation Practice Average Cost Estimates for Virginia, January 2000. Prepared by NRCS/VA. 21pp. <http://www.va.nrcs.usda.gov/DataTechRefs/Economics/Master.2%20List%20of%20Peach2: %20Costs.pdf>.

Vaught. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Westat. 2002. *AAP Screener Survey Production Range Report, Revision IV*. Westat, Inc. Rockville, MD.

CHAPTER 10
POLLUTANT LOADING METHODOLOGY

10.1 INTRODUCTION

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

The following pollutant loading/removal information is discussed in detail in this chapter:

- *Section 10.2* presents the structure of EPA's loading model for the CAAP industry. The model uses the model facility approach to develop estimated loading removal efficiencies associated with each regulatory option.
- *Section 10.3* discusses the model facility configuration. This section also describes input data, including wastewater generation and pollutant inputs, for the model facilities for flow-through, recirculating, and net pen systems. EPA's loading model relies on specific information about the species raised, culture system, pollutant inputs, and wastewater generation rates to accurately predict the pollutant removals associated with each regulatory option.
- *Section 10.4* discusses the effectiveness of the treatment technology units that compose the regulatory options. Each technology/BMP unit contains equations by which to calculate the reduction of the loadings associated with each regulatory option based on the facility characteristics.
- *Section 10.5* describes the current frequency of existing BMPs and treatment technologies at CAAP facilities.
- *Section 10.6* discusses the loading model structure and provides an example calculation.
- *Section 10.7* provides pollutant removals by model facility for the proposed options.

10.1.1 Regulatory Options

EPA developed three regulatory options for CAAP facilities:

- Option 1—solids removal through treatment technologies and BMPs.

- Option 2—BMP plan for pathogen control, prevention of nonnative species escapement, and minimization of drugs and chemicals.
- Option 3—additional solids control through treatment technologies.

Table 10.1-1 presents the treatment technologies and BMPs for each proposed option by subcategory. EPA describes the development of this set of options in more detail in Section 9.1 of this document. EPA used the combination of pollutant control technologies and BMPs shown in Table 10.1-1 as the basis for pollutant reductions in the pollutant loading models. These combinations of control technologies and BMPs reflect the pollutant reduction strategies that EPA found effective for removing the types of pollutants found in CAAP effluents, including total suspended solids (TSS), biochemical oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP).

Table 10.1-1. Treatment Technologies and BMPs for Proposed Regulatory Options, by Subcategory

Regulatory Option	*Required BMPs and Technologies*	*Subcategory*			
		Flow-through		*Recirculating*	*Net Pen*
		Medium[a]	*Large*[a]		
Option 1	Sedimentation basin	**X**	**X**	**X**	
	Quiescent zones	**X**	**X**		
	BMP plan	**X**	**X**	**X**	**X**
	Compliance monitoring	**X**	**X**	**X**	
Option 2	Drug & chemical BMP plan		**X**	**X**	**X**
Option 3	Solids polishing		**X**	**X**	
	Compliance monitoring		**X**	**X**	
	Active feed monitoring				**X**

Note: “X” represents a required treatment technology or BMP component for an option.
[a] See section 9.3.1 for description of medium and large flow-through systems.

10.1.2 Approach for Estimating Loadings

EPA typically uses one of two approaches, a *facility-specific* approach or a *model facility* approach, to estimate pollutant loading reductions for an industry. In both cases, EPA evaluated combinations of regulatory options that are applied to subcategories, or groups, of facilities to determine estimates of pollutant removals. Facility-specific pollutant loading reduction estimates require detailed process and geographic information about individual facilities in an industry. These data typically include facility characteristics such as the amount of aquatic animals produced (e.g., pounds of aquatic animals), size or production capacity of the facility, water use, quantity and quality of wastewater generated, waste management operations currently in place (including design, pollutant loadings, and removal effectiveness data), monitoring data, geographic location, financial conditions, and any other industry-specific data (e.g., species of the aquatic animals, life stages produced, types of feed used, amount of feed used, and drugs and chemicals used) that might be required for the analyses. EPA uses each facility’s information to estimate the expected pollutant removals at that facility, based on the regulatory options applied to the subcategory for which the facility is classified.

When sufficient facility-specific data are not available, EPA uses model facilities to provide a reasonable representation of the industry. A model facility is created to characterize a group of actual facilities for which EPA has some key facility-specific information it can use to approximate the process and effluent. Thus, a model facility represents a reasonable approximation of facility-specific characteristics for a group of similar real facilities. EPA makes a series of assumptions about the model facility characteristics to create the reasonable assumptions. For the pollutant loading model facilities, EPA averaged a range of characteristics to account for some of the variation among facilities within a model facility grouping.

EPA developed model facilities to reflect CAAP facilities with specific production system, ownership, and species combinations. EPA uses the average production value to represent all facilities within the group of facilities characterized by a model facility. For example, the model facility representing 44 medium (defined as facilities that produce 100,000 lb/yr to 475,000 lb/yr) flow-through facilities, which are state-owned and produce trout stockers, have an annual average production of 224,193 lb (the production actually ranges from 100,800 lb/yr to 433,915 lb/yr). The facility size and configuration, water use, wastewater generation, and other facility characteristics for the *state–flow-through–trout–stockers–medium* model facility are based on this annual average production of 224,193 lb.

EPA based these model facilities on data gathered during site visits, information provided by industry members and their associations, and other publicly available information. EPA estimated the number of facilities represented by each model using data from the Aquatic Animal Production (AAP) screener survey (Westat, 2002), in conjunction with information from the U.S. Department of Agriculture (USDA) 1998 Census of Aquaculture (USDA, 2000). EPA estimated pollutant loading reductions for each model facility and then calculated industry-level loading reductions by multiplying model facility reductions by the estimated number of facilities required to implement the treatment technology or management practice in each model category. For the CAAP industry, EPA chose a model facility approach to estimate the pollutant reductions because detailed information about the scope of the industry was not available. EPA expects to obtain more detailed facility-level information, although not on every facility, through the detailed survey (USEPA, 2002a).

EPA designed the model facility approach to capture the key characteristics (model facility configuration) of individual facilities, based on the Census of Aquaculture (USDA, 2000) and the AAP screener survey (Westat, 2002), by averaging these key characteristics and then representing the averages as a model facility. Using this approach, EPA characterized every facility according to specific attributes, which included production system type, species, and dollar level of production. EPA estimated or calculated other key attributes for each of the model facilities, including system inputs (e.g., feed), estimated pollutant loadings, discharge flow characteristics, and geographic data. EPA then linked all of these attributes and characteristics into option modules using Microsoft Excel as a computing platform to enable ease of changes to model facility assumptions and characteristics, as well as ease of calculation.

Control technology options and BMPs used to prevent the discharge of pollutants into the environment were linked in the unit loading modules, which calculated an estimated loading removal efficiency of the component based on estimates of pollutant reductions. EPA used sampling data, industry experts, and technical literature as sources of pollutant removal efficiencies for the components making up each regulatory option. For each model facility, EPA applied combinations of technologies and BMPs, given the model facility configuration characteristics (e.g., system type, size, and species). EPA adjusted the total loading removal efficiency of the component with a frequency factor that accounts for CAAP facilities that already have that technology or management practice in place. EPA used this adjusted loading estimate, which reflects the number of facilities that are subject to the proposed regulations, to determine the estimated national pollutant loading reductions associated with the proposed pollutant control technologies or management practices for each of the model facility types.

10.1.3 Basic Model Assumptions

EPA used annual facility production rates in the pollutant loading models to estimate the amount of feed added to a facility. The feed input drives the pollutant output from a facility. EPA used annual pollutant loadings, based on average annual production at a facility, as a basis for decision-making to account for the impacts of production variability on the model facility outputs. One source of this variation is the natural growing cycle of the aquatic animals; that is, small fish grow fast, but they add little biomass to a system, whereas larger fish grow more slowly, but add larger biomass to a system. Many CAAP facilities have multiple production units with different sizes and cohorts of animals in production at a given time. These multiple production units often combine effluent streams into one or two discrete conveyances. Although commercial CAAP facilities attempt to maintain maximum biomass in the culture facilities at all times to maximize production, there is often month-to-month variation within a facility. In a multiple-cohort practice, where different sizes of fish are in a system at one time, the biomass can have a narrower range at any given time. Many noncommercial facilities have a goal of producing a single cohort (generational group of animals) for natural resources enhancement. In a single cropping (a single cohort of animals from start to finish in a production unit, such as a pond or tank) management practice, the biomass in a production unit increases throughout the growing cycle. For both cases (single- and multiple-cohort production systems), the discharge varies in pollutant loadings over time, depending on the biomass of animals in the production units at a given time.

Availability of seed stock or fingerlings is another factor that strongly influences the size distribution of animals at a facility. Trout eggs, particularly those species and strains used for commercial production of foodfish, are usually available all year. The eggs of other species, such as hybrid striped bass, are typically available only when naturally spawning broodstock are available (in the spring). Another factor affecting growth and feed inputs is temperature, which influences growth of the cold-blooded animals grown in most CAAP facilities. Most aquatic animals grow in a defined range of water temperatures; for example, trout grow best at temperatures of 52 to 67 ºF and remain relatively dormant at temperatures below 41 ºF.

EPA based the pollutant loading model on several primary assumptions:

- Feed offered to the cultured species contributes to pollutant discharges in two ways. First, metabolic wastes and unmetabolized feed consumed by the cultured species are contained in the feces. Second, uneaten feed settles and increases the pollutant loading in the culture water. Thus, feed inputs to the systems drive the quality of effluents from CAAP facilities.
- Feed conversion ratios (FCRs), although they vary among species and production systems, geographically, and by size or age of the animal, determine the amount of feed put into CAAP facility production systems. To determine the annual amount of feed used at a CAAP facility, EPA multiplied the annual production for a model facility by the FCR. EPA evaluated the technical literature for information about FCRs (Hochheimer and Westers, 2002a) and found the reported values to vary, especially by system type and species. EPA assumed that using average values for predominant species (e.g., catfish, trout, hybrid striped bass, and salmon), which are also the FCRs reported in the literature, in estimating pollutant loadings was a reasonable approach. The averages reflect some of the variation that occurs among species and within a system type. EPA used average FCRs for each production system to estimate the feed inputs, which translate into pollutant loadings to a model facility (Table 10.1-2).

Table 10.1-2. Feed Conversion Ratios

System Type	*Initial FCR*	*Treatment/BMP*	*New FCR*
Flow-through	1.4	—	—
Recirculating	1.6	—	—
Net Pen	1.2	Active feed monitoring	1.0

Source: Hochheimer and Westers, 2002a.

- EPA received several comments from industry representatives regarding FCRs. The comments ranged from "FCRs are species- and site-specific" (Rice, 2002) to "FCRs are constantly changing" (Rheault, 2002). Several commenters thought the FCRs were too low (Engle, 2002; Pierce, 2002), and some thought EPA had estimated too high (Plemmons, 2002). As a result of these comments, EPA verified the assumed FCRs with other industry sources (Hinshaw, 2002, personal communication; MacMillan, 2002, personal communication). EPA will continue to evaluate the impact of different FCR assumptions.
- Although EPA found TSS, BOD, nitrogen, phosphorus, some metals (e.g., aluminum, barium, boron, copper, iron, manganese, selenium, and zinc), and a few organic compounds (e.g., bis (2-ethylhexyl) phthalate, hexanoic acid, P-cresol, phenol) present in effluents from CAAP facilities during sampling events, EPA focused its modeling efforts on TSS, BOD, TN, and TP. Most of the metals and organic compounds found in the sampled effluents were associated with the solids fraction in the effluent, so removing the solids would remove substantial portions of the metals and organic compounds as well.

- Technology options and BMPs have typical, definable, and steady-state efficiency rates of removing specific pollutants from water.
- Certain technologies are more applicable to some system types and flows than to others.
- EPA developed the pollutant loadings models for estimating the fate of TSS, BOD, TN, and TP in CAAP facilities. EPA had insufficient data to determine the pollutant removal efficiencies for drugs and chemicals used at CAAP facilities. Other special pollutants, such as escaping animals and aquatic animal pathogens, do not have pollutant removal efficiencies available for EPA to use in modeling.

10.1.3.1 Feed Inputs

EPA assumed the sources of pollutant loadings in CAAP facility production systems are the feed input and resulting metabolic wastes generated by the aquatic animals. The pollutant loadings calculated in the loading model were based on the feed input to the system and the feed-to-pollutant calculation, as described in the following discussion. The feed input to the model facility system was obtained by multiplying the model facility production, which was determined by analysis of the AAP screener results (see Section 10.3 for more details), by the initial FCR (listed in Table 10.1-2) for the CAAP facility.

EPA obtained the amount of feed input to each system using the following equation:

Feed input = model facility production * FCR

Where:

Model facility production = the average yearly production at the model facility (pounds)

FCR = the initial feed conversion ratio for the production system (pounds of feed per pound of fish produced).

10.1.3.2 Feed-to-Pollutant Conversion Factors

EPA only modeled pollutant generation as a function of feed inputs, which are the feed and associated metabolic wastes. The Agency used values for the feed-to-pollutant conversion factors (Table 10.1-3) in the loading model to represent the range of values found in literature reviews (Hochheimer and Westers, 2002a).

Table 10.1-3. Feed-to-Pollutant Conversion Factors

Pollutant	*Conversion Factor*
BOD	0.35
TN	0.03
TP	0.005
TSS	0.3

Source: Hochheimer and Westers, 2002a.

EPA found studies that determine the pollutants associated with feeding fish are often done in controlled laboratory situations using tanks with static water. The feed-to-pollutant conversion factors vary somewhat by species and the constituents in the feed, so EPA used typical values found in the literature to represent some of this variability. For the purpose of estimating pollutant loadings, EPA assumed that all feed added to a production system is consumed and undergoes some metabolic conversion by the aquatic animals. The resulting pollutants were estimated using the conversion factors in Table 10.1-3. Although feed conversion ratios greater than 1 indicate potentially uneaten feed, the amount of uneaten feed could vary considerably on a daily basis in a given production unit. Some of the factors that contribute to this variation are stress to the animals (e.g., changes in dissolved oxygen, spikes in production unit ammonia, unusual activity at the production facility, or a recent storm), water temperature, age of the aquatic animal, and the presence of disease. The mass of pollutants associated with unmetabolized feed are greater than those that are consumed and undergo the metabolic processes of the aquatic animals, so EPA used the more conservative value in the loading models. EPA used this assumption in all cases except active feed monitoring in net pens.

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

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

Where:

Annual feed input is the amount of feed distributed to the production system (pounds per year).

Feed-to-pollutant conversion factor converts feed inputs into pollutant loadings.

10.1.3.3 Production System Treatment Trains

EPA's loading model consists of combinations of regulatory options, which are combinations of pollutant control technologies and BMPs that are added to achieve increasing levels of pollutant loading reduction. EPA uses specific combinations of pollutant control technologies and BMPs (or treatment trains) for a model facility in estimating pollutant reductions. The loading model first estimates a raw wastewater pollutant loading based on feed conversion ratios and feed inputs. As the wastewater flows through different components of the treatment train, pollutants are removed. The loading model calculates pollutant loadings, not concentrations.

Figure 10.1-1 illustrates the treatment train for flow-through systems. Option 1 for flow-through systems consist of a quiescent zone coupled with a sedimentation basin and a BMP plan for solids removal. For the purpose of analysis, EPA assumed that all pollutant removals from the quiescent zone are conveyed to the sedimentation basin. The drug and chemical BMP plan is the only additional component of Option 2. Because this plan is targeted at only special pollutants (drugs and chemicals) for which EPA has no BMP efficiency removals/rates, the Agency could not include any pollutant removals for TSS, BOD, TN, and TP under Option 2. Solids polishing is the only additional component of Option 3 in flow-through systems.

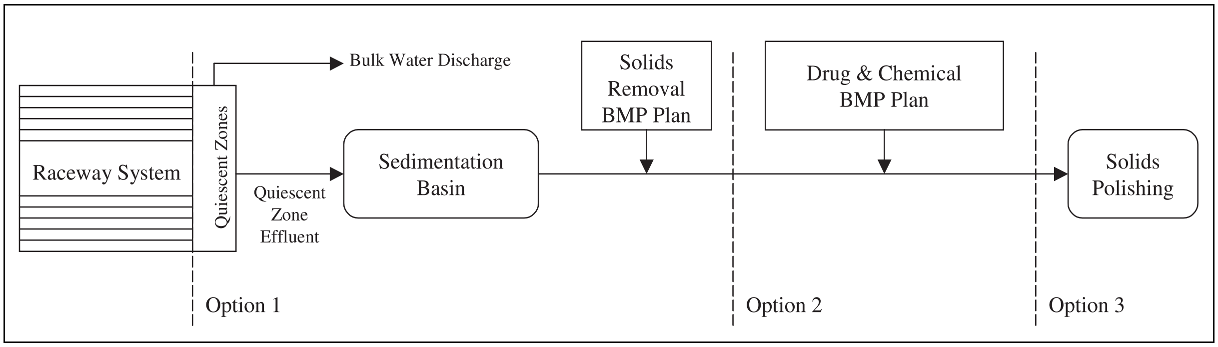


Figure 10.1-1. Flow-through Systems

For recirculating systems, Option 1 consists of the sedimentation basin and solids removal BMP plan. EPA assumed that all of the daily discharge would be conveyed to the sedimentation basin for treatment. The drug and chemical BMP plan is the only additional component of Option 2. Similar to flow-through systems, EPA targeted the drug and chemical BMP plan specifically for special pollutants (drugs and chemicals), for which EPA has no BMP efficiency removals. EPA did not include any pollutant removals for TSS, BOD, TN, and TP at Option 2. In recirculating systems, solids polishing is the only additional component of Option 3. Figure 10.1-2 illustrates the treatment train for recirculating systems. The treatment train includes only treatment practices for the wastewater discharge component of the recirculating system. Treatment components in the recirculating systems used for the process culture water, such as biological filters for ammonia removal, oxygenators, or internal solids collection devices, were not included in the treatment options. Also, treatment practices, such as biological treatment, to reduce BOD in the effluent were not evaluated.

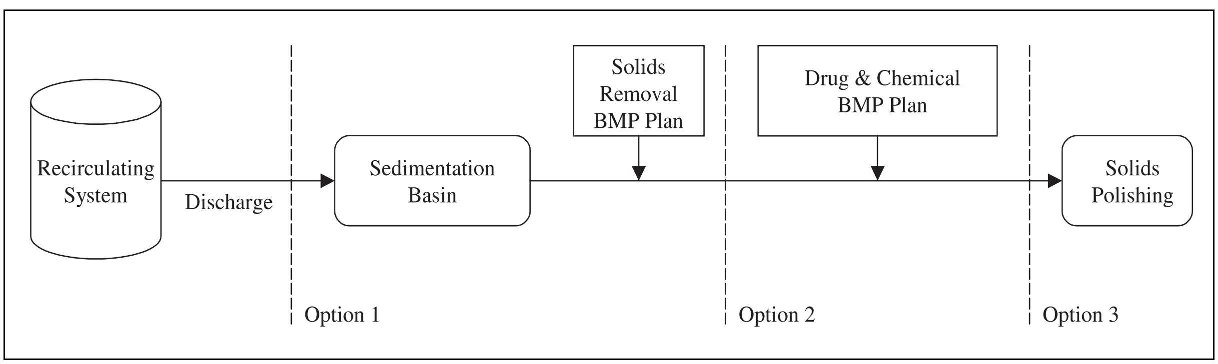


Figure 10.1-2. Recirculating System

Figure 10.1-3 illustrates the treatment train for net pen systems. Option 1 includes pollutant removals with feed management and the solids removal BMP plan. The pollutant reductions estimated for Option 1 are based on decreasing the FCR of the production system. Feed management is a management practice that was considered as part of Option 1 for all net pen operations, but was not required in the proposed regulation. The drug and chemical BMP plan is the only additional component of Option 2. Similar to flow-through and recirculating systems, EPA could not include any pollutant removals for TSS, BOD, TN, and TP. Active feed monitoring is the only additional component of Option 3.

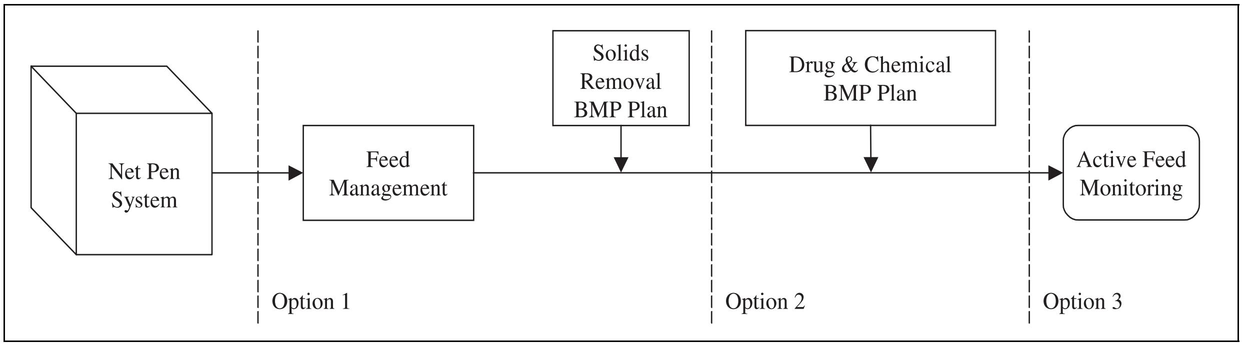


Figure 10.1-3. Net Pen System

10.2 LOADING MODEL STRUCTURE

EPA estimated the loading reduction associated with each of the regulatory options under consideration. EPA estimated loading reductions based on the implementation of BMPs and control technologies that have known pollutant removal efficiencies, as demonstrated by facilities in the CAAP facility industry.

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

- Model facility configuration
- Treatment/BMP modules
- Frequency factors
- Output data

Each module calculates loading reductions for a specific wastewater treatment technology or BMP (e.g., a primary settling basin) based on loading reductions for the specific model facility characteristics. Frequency factors are then applied to the loading reductions to weight the reductions by the estimated percentage of operations that already have that treatment technology or practice in place. EPA summed these weighted facility reductions for each regulatory option and model facility for those facilities without treatment.

10.2.1 Model Facility Configuration

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

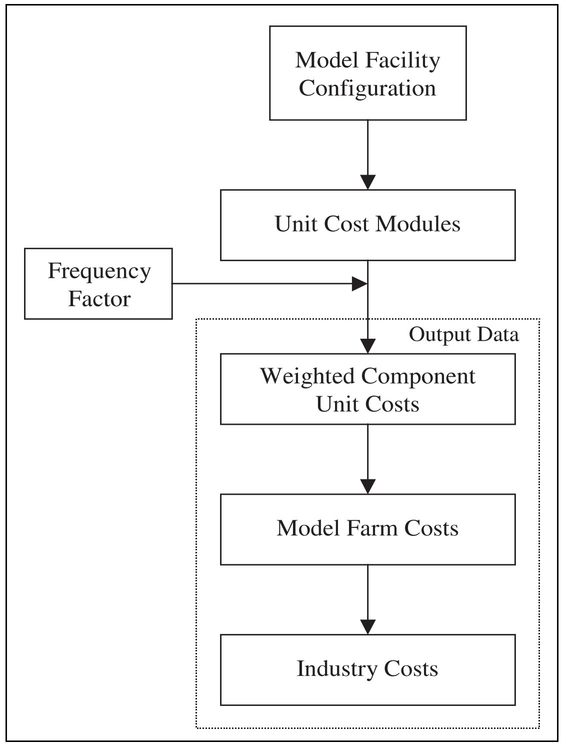


Figure 10.2-1. Schematic of Loading Model Structure

Input data to the model facilities includes the following:

- Number of facilities for a combination of system types, sizes, culture species, facility types, and locations.
- Technologies and BMPs by system type and facility size.
- Pollutant removals of technology options and BMPs.
- Average daily flow by system type and facility size.
- Estimates of annual production and price per pound.
- Data associated with feeding practices, including feeding in pounds per day and pollutant concentrations associated with feed.

10.2.2 Unit Loading Modules

The unit loading modules contain the loading information for each component, BMP, or treatment technology contained in the regulatory options. The loading modules calculate the pollutant removals for the model facilities, based on culture species and production system, using pollutant-specific removals for each of the regulatory options. The various loading factors are discussed in Section 10.3. The unit loading modules are used in conjunction with the frequency factors (see Section 10.5) to determine the pollutant loading for each segment of the industry.

10.2.3 Frequency Factors

EPA recognized that some individual facilities have already implemented some of the treatment technologies or BMPs included as part of the proposed options. When estimating pollutant loadings for implementing the proposed options across the entire subcategory nationwide, EPA did not include pollutant removals for BMPs or treatment technologies already in place.

EPA determined the current frequency of existing BMPs and treatment technologies at CAAP facilities based on existing NPDES permit requirements, screener survey responses, site visits, and sampling visits and information provided by the industry. EPA used this occurrence frequency to estimate the pollutant removals resulting from wastewater treatment technologies and BMPs already in use at CAAP facilities. Frequency factors are discussed in greater detail in Section 10.5.

10.2.4 Output Data

Output data from the loading model provide estimates of baseline pollutant loadings discharged and incremental pollutant removals associated with each regulatory option. Section 10.7 discusses the output data in more detail.

10.3 MODEL FACILITY CONFIGURATION

EPA defined model facilities for flow-through, recirculating, and net pen systems based on species, ownership (e.g., commercial, federal, state) and facility production size.

10.3.1 Flow-through Systems

The basic flow-through system model facility consists of a series of raceways and a treatment train of pollutant control technologies, including a quiescent zone, an offline settling basin, and a microscreen filter. Site visits (Tetra Tech, 2002d; Tetra Tech, 2002e; Tetra Tech, 2002f) and screener data (Westat, 2002) indicated that smaller flow-through facilities also operate circular tanks, earthen raceways, and flow-through concrete or earthen ponds. EPA assumed that raceways are the predominant systems used in flow-through facilities at the sizes being considered by the proposed regulation.

EPA developed raceway configurations from information obtained during site visits and conversations with AAP aquaculture industry representatives (Hinshaw, 2002, personal communication; Tetra Tech, 2002d; Tetra Tech, 2002e; Tetra Tech, 2002f). For flow-through systems, EPA developed the following physical attributes:

- Annual production (pounds of aquatic animals)
- Number of facilities
- Total facility flow rate (gallons per minute of water flowing through the facility)
- Feed conversion ratio (pounds of feed per pound of animal produced)
- Loading density (pounds of fish per cubic foot of raceway)
- Raceway dimensions
  - – Length of individual raceways (feet)

  - – Width of individual raceways (feet)
  - – Depth of individual raceways (feet)
  - – Volume of individual raceway (cubic feet)

- Number of raceways at a facility
- Loadings from raceways (pounds of pollutants in the raw effluent)

10.3.1.1 Annual Production

For flow-through systems EPA developed model facilities for facilities producing 100,000 lb/yr up to 475,000 lb/yr and facilities producing 475,000 lb/yr or more. EPA sorted data from the AAP screener survey (Westat, 2002) representing a species, lifestage (e.g., food-size or stockers), and facility type (e.g., commercial, federal, state) into two production groups, facilities producing 100,000 lb/yr up to 475,000 lb/yr (medium) and facilities producing 475,000 lb/yr or more (large). EPA then averaged all of the facilities from the AAP screener survey that fell within a species-lifestage-facility type combination for medium and large facility size classes to develop the model facility. For example, EPA grouped all seven of the federal (facility type) facilities that produce trout (species) stockers (lifestage) in flow-through systems producing 100,000 lb/yr up to 475,000 lb/yr as medium facilities. Table 10.3.1 provides details on the annual production ranges and average annual production used in the flow-through system calculations. Section 9.3 describes EPA's development of model facility size classifications in more detail.

EPA evaluated the limited available data, including the AAP screener survey data (Westat, 2002) and site visit information (see Chapter 3), and found nothing to indicate that the wide range of facility sizes represented by the average production values used as input for the model facilities in the large size class would misrepresent the range of facilities that made up the class. Although larger facilities can realize economies of scale in production costs, EPA was not able to find any differences in waste treatment or effluent quality characteristics for the larger systems in the range. Thus, EPA assumed the average facility sizes could accurately represent the range of facilities in the size class. (This observation holds for the ranges in facility sizes for recirculating and net pen systems as well.) EPA will evaluate the detailed survey data to verify this assumption.

10.3.1.2 Number of Facilities

Table 10.3-1 presents the number of facilities represented by each flow-through model facility group. EPA used the AAP screener survey results (Westat, 2002) for the counts of facilities in each model facility group.

10.3.1.3 Total Flow Rate

Flow-through systems require a high volume of water to flush wastes from the production area and make oxygen available to the aquatic animals. Most flow-through systems are designed and operated with water flows that exchange or replace water in the system tanks or raceways 3 to 6 times per hour (Hinshaw and Fornshell, 2002), which translates into a system flow rate of 1 gallon per minute per 100 lb of annual production (Hochheimer and Westers, 2002b).

Table 10.3-1. Model Facility Information

Model Facility	*Size*	*Number of Facilities*[a]	*Production Range (lb/yr)*[b]	*Average Production (lb/yr)*[b]
Trout-Commercial-Flow-through	Medium	22	100,000-370,000	208,986
	Large	8	592,900-8,260,815	2,499,170
Trout-State-Flow-through	Medium	< 5	—	—
	Large	< 5	—	—
Trout-Stockers-Commercial-Flow-through	Medium	5	128,000–317,000	192,137
Trout-Stockers-Federal- Flow-through	Medium	7	106,788–309,885	208,296
	Large	< 5	—	—
Trout-Stockers-State-Flow-through	Medium	44	100,800–433,915	224,193
	Large	< 5	—	—
Trout-Stockers-Other-Flow-through	Medium	< 5	—	—
	Large	< 5	—	—
Tilapia-Commercial-Flow–through	Medium	< 5	—	—
	Large	< 5	—	—
Striped Bass-Commercial-Flow-through	Medium	< 5	—	—
Salmon-Other-Flow-through	Large	< 5	—	—

[a] <5 indicates a group with fewer than 5 facilities and is reported in this manner to protect the confidentiality of individual facilities.
[b] Model facility groups with fewer than 5 facilities are not reported.

10.3.1.4 Feed Conversion Ratio

EPA used an FCR of 1.4 for all flow-through systems. (See Section 10.1.3 for additional information on FCR values and assumptions.)

10.3.1.5 Loading Density

Based on industry input (Hinshaw, 2002, personal communication; Plemmons, 2002), EPA assumed a loading density of 3 lb/ft^3 for sizing of facilities (determining the estimated number of raceways for a given facility size).

10.3.1.6 Raceway Dimensions

EPA assumed the raceway size for medium facilities to be 150 ft long by 14 ft wide by 3 ft deep (volume = 6,300 ft^3). The raceway size for large facilities was assumed to be 175 ft long by 18 ft wide by 3 ft deep (volume = 9,450 ft^3).

10.3.1.7 Number of Raceways

To estimate the number of raceways at a flow-through facility, EPA used the following calculation:

Number of raceways = annual production/(loading density * volume per raceway)

Where:

- Number of raceways is the number for a model facility type (rounded up to the nearest integer)
- Annual production is the average production for the model facility type in pounds
- Loading density is 3 lb/ft^3 (Hinshaw, 2002, personal communication; Plemmons, 2002)
- Volume per raceway is 6,300 ft^3 for medium facilities and 9,450 ft^3 for large facilities

10.3.1.8 Loadings from Raceways

To estimate the pollutant loadings from each raceway, EPA used the pollutant loading values presented in Table 10.1-3 and the methodology described in Section 10.1.3 to estimate values for BOD, TN, TP, and TSS. Table 10.3-2 provides the estimated raw pollutant loadings for flow-through facilities.

Table 10.3-2. Raw Loading Estimates (per Facility) for Flow-through Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Trout-Food-size-State-Medium-Flow-through	119,959	10,282	1,714	102,822
Trout-Food-size-State-Large-Flow-through	269,500	23,100	3,850	231,000
Trout-Food-size-Commercial-Medium-Flow-through	102,403	8,777	1,463	87,774
Trout-Food-size-Commercial-Large-Flow-through	1,224,593	104,965	17,494	1,049,651
Trout-Stockers-Federal-Medium-Flow-through	102,065	8,748	1,458	87,484
Trout-Stockers-Federal-Large-Flow-through	671,300	57,540	9,590	575,400
Trout-Stockers-Commercial-Medium-Flow-through	94,147	8,070	1,345	80,698
Trout-Stockers-Other-Medium-Flow-through	186,830	16,014	2,669	160,140
Trout-Stockers-Other-Large-Flow-through	235,200	20,160	3,360	201,600
Trout-Stockers-State-Medium-Flow-through	109,855	9,416	1,569	94,161
Trout-Stockers-State-Large-Flow-through	242,963	20,825	3,471	208,254
Tilapia-Food-size-Commercial-Medium-Flow-through	120,867	10,360	1,727	103,600
Tilapia-Food-size-Commercial-Large-Flow-through	490,000	42,000	7,000	420,000
Striped Bass-Food-size-Commercial-Medium-Flow-through	60,409	5,178	863	51,779
Salmon-Food-size-Other-Large-Flow-through	1,160,871	99,503	16,584	995,033

10.3.2 Alaska Flow-through Systems

Alaskan salmon producers refer to their production operations as "ocean ranching" in which hatchery fish are released into coastal areas to supplement the natural populations. Alaska salmon production systems represent a slight departure from traditional flow-through culture systems. Because of the high costs associated with the disposal of solids and good tidal flushing in the waters adjacent to the facilities, most facilities do not operate wastewater treatment units for the collection of solids. Otherwise, facilities operate much like all other flow-through systems.

Because EPA received facility-specific data from the Alaska facilities, the Agency modeled each facility separately to determine pollutant removals.

10.3.2.1 Annual Production

EPA estimated production data for each facility using 2000 hatchery production data reported in Alaska Fish and Game's *Alaska Salmon Enhancement Program 2000 Annual Report* (McNair, 2001). EPA estimated hatchery releases by facilities using a conversion of 0.4 g per fish for pink and chum salmon and 20 g per fish for coho, chinook, sockeye, and other salmon species, based on industry-provided information (Tetra Tech, 2002i). EPA modeled only the facilities producing more than 100,000 lb/yr. Table 10.3-3 presents production estimates for each Alaska salmon facility producing more than 100,000 lb/yr.

Table 10.3-3. Alaska Salmon Producers

Facility	*Production (lb/yr)*	*Facility*	*Production (lb/yr)*
Facility 1	104,738	Facility 10	207,649
Facility 2	201,052	Facility 11	985,194
Facility 3	204,139	Facility 12	116,636
Facility 4	144,436	Facility 13	366,030
Facility 5	135,510	Facility 14	244,543
Facility 6	403,515	Facility 15	571,095
Facility 7	150,822	Facility 16	145,089
Facility 8	125,720	Facility 17	222,290
Facility 9	153,371	Facility 18	250,047

10.3.2.2 Number of Facilities

EPA estimated the number of facilities based on 2000 hatchery production data reported in Alaska Fish and Game's *Alaska Salmon Enhancement Program 2000 Annual Report* (McNair, 2001). Table 10.3-3 shows the 18 Alaska facilities that EPA used to estimate loadings.

10.3.2.3 Total Flow Rate

EPA used a system flow rate of 1 gallon per minute per 100 pounds of annual production, which is the same flow rate used for other flow-through systems (Hochheimer and Westers, 2002b).

10.3.2.4 Feed Conversion Ratio

EPA used a feed conversion ratio of 1.4 for all flow-through systems. (See Section 10.1.3 for additional information on FCR values and assumptions.)

10.3.2.5 Loading Density

Based on industry input (Hinshaw, 2002, personal communication; Plemmons, 2002), EPA assumed a loading density of 3 lb/ft^3 for sizing of facilities (determining the estimated number of raceways for a given facility size).

10.3.2.6 Raceway Dimensions

EPA used the raceway size of 150 ft long by 14 ft wide by 3 ft deep, which is the same size as the medium-sized flow-through facilities in other states.

10.3.2.7 Number of Raceways

To estimate the number of raceways at a flow-through facility, EPA used the following calculation:

Number of raceways = annual production/(loading density * volume per raceway)

Where:

- Number of raceways is the number for a model facility type (rounded up to the nearest integer)
- Annual production is the average production for the model facility type in pounds
- Loading density is 3 lb/ft^3 (Hinshaw, 2002, personal communication; Plemmons, 2002)
- Volume per raceway is 6,300 ft^3 for medium facilities

10.3.2.8 Loadings from Raceways

To estimate the pollutant loadings from each raceway, EPA used the pollutant loading values presented in Table 10.1-3 and the methodology described in Section 10.1.3 to estimate values for BOD, TN, TP, and TSS. Table 10.3-4 provides the estimated raw pollutant loadings for Alaska flow-through facilities.

Table 10.3-4. Raw Loading Estimates (per Facility) for Alaska Flow-through Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Facility 1	51,322	4,399	733	43,990
Facility 2	98,515	8,444	1,407	84,442
Facility 3	100,028	8,574	1,429	85,738
Facility 4	70,774	6,066	1,011	60,663
Facility 5	66,400	5,691	949	56,914
Facility 6	75,152	6,442	1,074	64,416

Model Facility	BOD (lb/yr)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Facility 7	197,722	16,948	2,825	169,476
Facility 8	73,903	6,335	1,056	63,345
Facility 9	61,603	5,280	880	52,802
Facility 10	101,748	8,721	1,454	87,213
Facility 11	482,745	41,378	6,896	413,781
Facility 12	57,152	4,899	816	48,987
Facility 13	179,355	15,373	2,562	153,733
Facility 14	119,826	10,271	1,712	102,708
Facility 15	571,095	14,169	2,362	141,693
Facility 16	71,094	6,094	1,016	60,937
Facility 17	108,922	9,336	1,556	93,362
Facility 18	122,523	10,502	1,750	105,020

10.3.3 Recirculating Systems

Recirculating systems typically require inputs of relatively small volumes of water because water in these systems is continuously filtered and reused. The production water treatment process is designed to minimize water requirements, which results in a small-volume, concentrated waste stream that is discharged daily. For the loading modeling, EPA used a basic recirculating system configuration for the production system and support equipment (with no predefined internal process configuration) that produces a concentrated effluent. The effluent waste stream is treated with a sedimentation basin and microscreen.

EPA developed recirculating system configurations from information obtained during site visits (Tetra Tech, 2002a; Tetra Tech, 2002g; Tetra Tech, 2002h; USEPA, 2002d) and from AAP industry representatives (AES, 2001). For recirculating systems, EPA developed the following characteristics:

- Annual production (pounds of aquatic animals)
- Number of facilities
- Feed conversion ratio (pounds of feed per pound of animal produced)
- Loading density (pounds of fish per cubic foot of production system volume)
- Volume of the system (cubic feet)
- Daily discharge rate (gallons per minute of water flowing from the facility)
- Loadings in effluent (pounds of pollutants in the raw effluent)

10.3.3.1 Annual Production

For recirculating systems EPA developed one model facility to represent all facilities producing 100,000 lb/yr or more. EPA sorted data from the AAP screener survey

(Westat, 2002) representing a species, lifestage (e.g., food-size or stockers), and facility type (e.g., commercial, federal, state) into facilities producing greater than 100,000 lb/yr (large). EPA then averaged all of the species-lifestage-facility type combinations for the large facility size class to develop the model facility. Section 9.3 provides additional details on the development of production size ranges. Table 10.3-5 shows the production ranges and average production for recirculating facilities.

Table 10.3-5. Model Facility Information

Model Facility	*Size*	*Production Range (lb/yr)*	*Average Production (lb/yr)*	*Facilities Represented*
Tilapia-Recirculating	Large	200,000-525,000	351,643	5
Striped Bass-Recirculating	Large	–	–	< 5[a]

[a] <5 and "–" indicate a group with fewer than five facilities, reported in this, to protect the confidentiality of the individual facilities.

10.3.3.2 Number of Facilities

Table 10.3-5 presents the number of facilities represented by each recirculating system model facility group. EPA used the AAP screener survey results (Westat, 2002) for the counts of facilities in each model facility group.

10.3.3.3 Feed Conversion Ratio

EPA used a feed conversion ratio of 1.6 for all recirculating systems. (See Section 10.1.3 for additional information on FCR values and assumptions.)

10.3.3.4 Loading Density

EPA used the average stocking density of the culture species within the production system at maximum production levels for estimating the loading density. Information from site visits conducted at facilities operating recirculating production systems indicated loading densities of about 1 lb per gallon of culture water (Tetra Tech, 2002a; Tetra Tech, 2002g; Tetra Tech, 2002h) are common in the United States.

10.3.3.5 System Volume

EPA calculated the production system volume for recirculating systems using the model facility's annual production and loading density. The formula used to calculate production system volume is as follows:

Production system volume = facility annual production/loading density

where production system volume is reported in gallons, loading density is 1.0 lb/gal, and facility annual production is the average annual model facility production in pounds.

10.3.3.6 Daily Discharge Rate

Many recirculating systems are operated with a 10% makeup volume of water added daily to dilute the production water and replace water lost to evaporation and backwashing of the solids filters (Chen et al., 2002). Thus, recirculating systems have a continuous discharge consisting of the backwash from the solids filter and overflows resulting from the added makeup water. EPA calculated the daily discharge rate as

Daily discharge rate = production system volume * daily makeup factor

Where the daily discharge rate is in gallons per day, the production system volume is in gallons, and the daily makeup factor is 10% of the system volume per day.

10.3.3.7 Loadings from Recirculating Systems

To estimate the pollutant loadings from each recirculating system, EPA used the pollutant loading values presented in Table 10.1-3 and the methodology described in Section 10.1.3 to estimate values for BOD, TN, TP, and TSS. Table 10.3-6 provides the estimated raw pollutant loadings for recirculating system facilities.

Table 10.3-6. Raw Loading Estimates (per Facility) for Recirculating System Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Striped Bass-Food-size-Commercial-Large-Recirculating	688,800	59,040	9,840	590,400
Tilapia-Food-size-Commercial-Large-Recirculating	196,915	16,878	2,813	168,784

10.3.4 Net Pen Systems

Net pen systems are suspended or floating holding cages or nets used for the growout of the culture species. Net pen systems are located directly in the receiving water, and wastes are directly deposited from the net pen into the water. For the loading modeling, EPA used a net pen system physical configuration consisting of only the production system with no pollutant control technologies in place. EPA had observed at the site visits that some of the net pen facilities already have some of the BMPs in place (e.g., feed management, escapement plans, or active feed monitoring) and accounted for these in-place management practices with frequency factors.

EPA developed net pen system configurations from information obtained during site visits and conversations with AAP industry representatives (Tetra Tech, 2002b; Tetra Tech, 2002c) For net pen systems EPA developed the following characteristic:

- Annual production (pounds of aquatic animals)
- Number of facilities
- Feed conversion ratio (pounds of feed per pound of animal produced)
- Loading density (pounds of fish per cubic foot of net pen)
- Volume of the system (cubic feet)
- Number of net pens
- Loadings from net pens (pounds of pollutants in the raw effluent)

10.3.4.1 Annual Production

For net pen systems EPA developed one model facility to represent all facilities producing 100,000 lb/yr or more. EPA sorted data from the AAP screener survey (Westat, 2002) representing a species, lifestage (e.g., food-size), and facility type (e.g., commercial, federal, state) into facilities producing 100,000 lb (large) or more annually. All of the species-lifestage-facility type combinations for the large facility size class were then averaged to produce the model facility. Additional information on production system sizes for net pens is provided in Section 9.3. Table 10.3-7 provides production information for net pen facilities.

Table 10.3-7. Model Facility Information

Model Facility	*Size*	*Production Range (lb/yr)*	*Average Production (lb/yr)*	*Facilities Represented*
Salmon-Net Pens	Large	342,380–6,352,715	2,387,086	8

10.3.4.2 Number of Facilities

Table 10.3-7 presents the number of facilities represented by the net pen system model facility group. EPA used the AAP screener survey results (Westat, 2002) for the counts of facilities in each model facility group.

10.3.4.3 Feed Conversion Ratio

EPA used an initial feed conversion ratio of 1.2 for all net pen systems. (See Section 10.1.3 for additional information on FCR values and assumptions.)

10.3.4.4 Loading Density

EPA estimated that a loading density of 0.8 lb/ft^3 was applicable to the industry (Hochheimer and Westers, 2002c).

10.3.4.5 System Volume

The volume of individual nets was assumed to be 250,000 ft^3, based on site visit information (Tetra Tech, 2002b; Tetra Tech, 2002c).

10.3.4.6 Number of Net Pens

To estimate the number of net pens at a facility, EPA used the following calculation:

Number of net pens = annual production/(loading density * volume per net pen)

Where:

- Number of net pens is the number for a model facility type (rounded up to the nearest integer)
- Annual production is the average production for the model facility type in pounds
- Loading density is 0.8 lb/ft^3
- Volume per net pen is 250,000 ft^3 for all facilities

10.3.4.7 Loadings from Net Pen Systems

To estimate the loadings of pollutants from the net pen system model, EPA used the pollutant loading values presented in Table 10.1-3 and the methodology described in Section 10.1.3 to estimate values for BOD, TN, TP, and TSS. Table 10.3-8 provides the estimated raw pollutant loadings for net pen facilities.

Table 10.3-8. Raw Loading Estimates (per Facility) for Net Pen Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Salmon-Food-size-Commercial-Large-Net Pen	1,002,576	85,935	14,323	858,351

10.4 UNIT LOADING MODULES

Loading modules calculate the pollutant removal associated with a particular technology or practice for an AAP facility. Each loading module contains the pollutant-specific removal efficiencies of the system component.

- Description of technology or practice
- Pollutant removal efficiencies

10.4.1 Quiescent Zones

Quiescent zones are a technology control considered in Option 1 for all flow-through CAAP facilities as a part of primary solids removal.

10.4.1.1 Description of Technology or Practice

Quiescent zones are a practice used in raceway flow-through systems that use the last approximately 10% of the raceway as a settling area for solids. Quiescent zones placed at the bottom or end of each rearing unit or raceway allow for the settling of pollutants before they are discharged to other production units (when water is serially reused in several rearing units) or receiving waters. Because quiescent zones settle and store solids in the production system, the solids must be removed and further treated. EPA observed facilities treating these solids (and any water removed from the quiescent zone during cleaning) by concentrated, direct land application, or dewatering and composting. For most medium and large facilities, quiescent zones are coupled with an offline settling basin to concentrate the solids and water mixture vacuumed from the quiescent zone. Solids are stored in the basin and removed before exceeding the storage capacity of the basin (typically about once per month at large facilities). Treated water is decanted from the offline basin and discharged directly or combined with the bulk discharge stream. For estimating pollutant loadings, EPA assumed that quiescent zones are coupled with offline settling basins. Thus, treatment efficiencies and pollutant removals were estimated for the combination of a quiescent zone and settling basin, not each practice individually. EPA also assumed a single frequency factor for the quiescent zone–offline settling basin combination.

Quiescent zones usually are constructed with a wire mesh screen that extends from the bottom of the raceway to above the maximum water height to prohibit the cultured species from entering the quiescent zone. The reduction in the turbulence usually caused by the swimming action of the cultured species allows the solids to settle in the quiescent zone. The solids are then available to be efficiently removed from the system. Quiescent zones are usually cleaned on a regular schedule, typically once per week in medium to large systems (Hinshaw, personal communication, 2002; MacMillan, personal communication, 2002), to remove the settled solids. The Idaho BMP manual (IDEQ, n.d.) recommends a minimal quiescent zone cleaning frequency of once per month in upper raceways and twice per month in lower units. The settled solids must be removed regularly to prevent breakdown of particles and leaching of pollutants such as nutrients and BOD.

10.4.1.2 Pollutant Removal Efficiencies: Flow-Through Systems

EPA used pollutant removals specific to each pollutant to calculate the removal by the quiescent zones. EPA obtained pollutant removal efficiencies for quiescent zones from the technical literature (Hinshaw and Fornshell, 2002). Table 10.4-1 presents the removal efficiency for each pollutant modeled. The calculation used in the loading model to obtain the loading discharged from the quiescent zone is as follows:

Effluent pollutant loading = influent pollutant loading * (1 - removal efficiency)

Where:

Influent pollutant loading = the pollutant removal from the quiescent zone

Removal efficiency = the specific removal efficiency for the treatment unit

Table 10.4-1. Quiescent Zone Removal Efficiencies

Pollutant	*Removal Efficiency (%)*
BOD	94.0
TN	8.5
TP	17.7
TSS	51.2

10.4.2 Sedimentation Basins

Sedimentation basins are a technology control considered in Option 1 for all flow-through and recirculating CAAP facilities as a part of primary solids removal. Sedimentation basins at flow-through facilities can be in the form of offline or full-flow. Offline settling treats a portion of the flow-through effluent volume in which solids have been concentrated. Full-flow sedimentation basins treat all of the flow from flow-through systems and are sized to accommodate settling of solids prior to discharge. Full-flow settling requires large areas to accommodate the higher flow rates encountered in medium and large flow-through systems. EPA found only a few full-flow settling basins in medium-sized facilities and none in larger systems. When offline settling is used, treatment technologies to concentrate solids (e.g., quiescent zones) are also used. For recirculating systems sedimentation basins are used to treat the concentrated waste stream that is discharged from the recirculating system.

10.4.2.1 Description of Technology or Practice

Sedimentation basins (also called settling basins, settling ponds, sedimentation ponds, or sedimentation lagoons) are used extensively in the wastewater treatment industry (Metcalf and Eddy, 1991a) and are commonly found in many flow-through and recirculating CAAP facilities (Westat, 2002). Sedimentation basins are used to collect and store the solids captured in quiescent zones or other in-system pollutant removal practices. EPA assumed that all solids captured in the quiescent zone are vacuumed and conveyed to the offline sedimentation basin. Most sedimentation basins are used to produce a clarified effluent (for solids removal), but some sedimentation basins remove water from solids to produce a more concentrated sludge. Both of these applications of sedimentation basins are used and are important in CAAP systems.

Sedimentation basins are sized according to the settling time for the particles in the effluent and the desired final effluent quality. EPA based its estimated sedimentation basin pollutant reductions on information supplied by AAP industry representatives (Hinshaw, 2002, personal communication; MacMillan, 2002, personal communication). EPA also used pollutant reductions in the model that were specific to each pollutant. Based on information obtained during site visits, EPA expects recirculating systems to generate a maximum of about 10% of the system volume per day.

10.4.2.2 Pollutant Removal Efficiencies: Flow-through Systems and Recirculating Systems

EPA's loading model used pollutant removals specific to each pollutant to calculate the removal by the sedimentation basin. EPA obtained the removal for each pollutant from the technical literature (Hinshaw and Fornshell, 2002). These values used in the model are similar to those obtained in EPA sampling trips and are comparable to those reported in AAP industry publications (e.g., Boyd and Tucker, 1995). Table 10.4-2 presents the removal efficiency for each pollutant modeled.

Table 10.4-2. Sedimentation Basin Removal Efficiencies

Pollutant	*Removal Efficiency (%)*
BOD	79.0
TN	7.1
TP	29.1
TSS	84.1

Influent loadings to the sedimentation basin were derived differently for flow-through and recirculating systems. For flow-through systems, EPA assumed that the total loading removed by the quiescent zone would be conveyed to the sedimentation basin for treatment. For recirculating systems, the entire raw pollutant loading was conveyed to the sedimentation basin.

The loading model calculates the pollutant removal by using two calculations. First the influent loading is multiplied by (1 – removal efficiency) to obtain the loading discharged from the sedimentation basin. The loading removed is the influent loading multiplied by the removal efficiency. The calculations used for pollutant removals is as follows:

Effluent pollutant loading = influent pollutant loading * (1 - removal efficiency)
Loading removed = influent pollutant loading * removal efficiency

Where:

Influent pollutant loading = the pollutant loading entering the sedimentation basin
Removal efficiency = the specific removal efficiency for the treatment unit
Loading removed = the pollutant removal by the sedimentation basin

10.4.3 Feed Management

Feed management is a management practice that was considered as part of Option 1 for all net pen operations, but was not required in the proposed regulation.

10.4.3.1 Description of Technology or Practice

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

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

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

10.4.3.2 Pollutant Removal Efficiencies: Net Pen Systems

The pollutant removals for feed management in net pen systems are based on lowering the feed conversion ratio from 1.2 to 1.1, resulting in a removal efficiency of 8.3 % for all parameters. EPA site visits to net pen production facilities indicated FCRs of 1.1 could be obtained by salmon producers. The calculation for the removal efficiency is as follows:

Removal efficiency = (1 – (new FCR ÷ old FCR)) * 100

Where:

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

Old FCR = the estimated FCR obtained by the industry at baseline

10.4.4 BMP Plan

Solids control BMP plans are considered as a management practice for all CAAP facilities under Option 1. All requirements associated with the solids control BMP plans are assumed to be equal for all species and culture systems except net pens.

10.4.4.1 Description of Technology or Practice

Evaluating and planning site-specific activities to control the release of solids from CAAP facilities is a practice currently required in several EPA regions as part of individual and general NPDES permits (e.g., shrimp pond facilities in Texas, net pens in Maine, and flow-through facilities in Washington and Idaho). BMP plans in these permits require the facility operators to "develop a management plan for removed solids and prevention of excess feed from entering the system." The BMP plan also ensures planning for proper operation and maintenance of equipment, especially treatment control technologies. Implementation of the BMP plan results in a series of pollution prevention activities, such as ensuring that employees do not waste feed and planning for the implementation of other operation and maintenance (O&M) activities that could result in decreased pollutant discharges.

10.4.4.2 Pollutant Removal Efficiencies

Pollutant reductions realized as a result of a BMP plan would be highly variable and specific to each facility; therefore, EPA used pollutant reductions in only the loading model for net pens.

The pollutant removals for the solids management BMP plan in net pen systems are based on lowering the feed conversion ratio from 1.1 to 1.0, resulting in a removal efficiency of 9.1 for all parameters. Information obtained during EPA site visits at net pen production facilities and research of AAP industry publications indicated FCRs of 1.0 could be obtained (Fish Farmer Magazine, 2002). The calculation for the removal efficiency is as follows:

Removal efficiency = (1 – (new FCR ÷ old FCR)) * 100

Where:

New FCR = the FCR obtained with implementation of a solids management BMP plan

Old FCR = the estimated FCR obtained by the industry at baseline

10.4.5 Drug and Chemical BMP Plan

The drug and chemical BMP plan is proposed under Option 2 for large flow-through systems (producing 475,000 lb or more annually), all net pens, and all recirculating systems. All requirements associated with the drug and chemical BMP plan are estimated to be equal for all species and culture systems.

10.4.5.1 Description of Technology or Practice

The purpose of the drug and chemical BMP plan is to document the use of specific classes of drugs and chemicals in the production facility. The plan would also address the practices to minimize the accidental spill or release of drugs and chemicals.

10.4.5.2 Pollutant Removal Efficiencies

Pollutant reductions for BOD, TN, TP, and TSS are not expected to occur as a result of implementation of a drug and chemical BMP plan. This plan is proposed to reduce the discharge of special pollutants (drugs and chemicals) only. Therefore, EPA could not use pollutant reductions for BOD, TN, TP, and TSS in the loading model.

10.4.6 Additional Solids Removal (Solids Polishing)

Additional solids removal is considered under Option 3 for flow-through systems and recirculating systems.

10.4.6.1 Description of Technology or Practice

Solids polishing refers to the use of a wastewater treatment technology to further reduce solids discharged from sedimentation basins used to treat flow-through and recirculating systems. Several technologies are available, including microscreen filters and polishing ponds. Microscreen filters consist of fine mesh filters that are usually fitted to a rotating drum. The wastewater stream is pumped into the inside of the drum, and solids are removed from the effluent as the water passes through the screen. The screen size usually varies between 60 and 90 microns. The filters are equipped with automatic backwash systems that remove collected solids from the screen and direct them to further treatment or solids storage (Chen et al., 1994).

EPA assumed that a rotary microscreen filter would be used so that clogging problems could be minimized. A small motor rotates the screen to enhance performance, and automatic backwash jets are activated when the pressure drop across the screen reaches a set level (Chen et al., 1994). The backwash solids and water are usually conveyed to a solids storage tank or basin to await proper disposal. Commercial units are readily available for the flow rates and TSS concentrations expected from sedimentation basins at CAAP facilities.

10.4.6.2 Pollutant Removal Efficiencies

EPA used CAPDET (Hydromantis, 2001) to estimate pollutant reduction rates for microscreen filters. CAPDET provided estimated pollutant reductions of 60% for TSS and 50% for BOD, TN, and TP. EPA found that these values were supported in the technical literature: Metcalf and Eddy (1991b) indicated pollutant removals for microscreens of between 10% and 80% for suspended solids; other sources indicated phosphorus removals of up to 80% with microscreens (Chen et al., 1994). EPA opted for the more conservative 60% removal for TSS and 50% removals for BOD, TN, and TP because of the scarcity of data from AAP facilities.

10.4.7 Active Feed Monitoring

Active feed monitoring is considered as a management practice in Option 3 for all net pen facilities. Active feed monitoring is a relatively new but proven technology used by some facility operators in the salmon industry. Some type of remote monitoring equipment, such as an underwater video camera, is lowered from the surface to the bottom of a net pen during feeding to monitor for uneaten feed pellets as they pass by the video camera.

10.4.7.1 Description of Technology or Practice

The goal of active feed monitoring is to further reduce pollutant loadings associated with feeding activities. A variety of technologies could be used, including video cameras with human or computer interfaces to detect passing feed pellets. A new NPDES permit issued in Maine (USEPA, 2002b) also suggests that ultrasonic equipment might be available. Most facilities that use this technology use a video monitor at the surface that is connected to the video camera. An employee watches the monitor for feed pellets passing by the video camera and then stops feeding activity when a predetermined number of pellets (typically only two or three) pass the camera.

10.4.7.2 Pollutant Removal Efficiencies: Net Pen Systems

EPA estimated that pollutant reductions associated with active feed monitoring would be about 5.0% for all pollutants.

10.5 FREQUENCY FACTORS

Applying the frequency factors to the modules allows the loading model to account for the treatment units and BMPs already in place. Essentially, EPA adjusts the component loading removal to account for facilities that already have the component in place. Such facilities would not have to install and operate a new component as a result of the proposed regulation.

EPA estimated frequency factors based on sources such as those listed below. (Each source was considered along with its limitations.)

- EPA site visit information was used to assess general practices of CAAP facility operations and how they vary among regions and size classes.
- The AAP screener survey was used to assess general practices of CAAP facility operations and how they vary among regions and size classes.
- EPA used observations on CAAP facility operations by industry experts, who were contacted to provide insight into operations and practices, especially where data were limited or not publicly available.
- *State Compendium: Programs and Regulatory Activities Related to Aquatic Animal Production* (see Chapter 9) was used to estimate frequency factors, based on current requirements for treatment technologies and BMPs that already apply to CAAP facilities in various states (MDA, 1995). For example, BMP plans are required for all facilities with permits in Idaho and Washington, so the facilities in these states were assumed to have solids control BMP plans in place.

10.5.1 Quiescent Zones

Quiescent zones are commonly used by flow-through CAAP facilities to remove solids. EPA developed frequency factors for quiescent zones in flow-through CAAP facilities from the AAP screener survey (Westat, 2002), and they are presented in Table 10.5-1.

Table 10.5-1. Quiescent Zone Frequency Factors

Species	*Model*	*Frequency Factor*
Trout-Food-size-Commercial-Flow-through	Medium	0.91
	Large	1.00
Trout-Food-size-State-Flow-through	Medium	1.00
	Large	1.00
Trout-Stockers-Commercial-Flow-through	Medium	1.00
Trout-Stockers-Federal-Flow-through	Medium	0.57
	Large	0.50
Trout-Stockers-State-Flow-through	Medium	0.91
	Large	1.00
Trout-Stockers-Other-Flow-through	Medium	1.00
	Large	1.00
Tilapia-Food-size-Commercial-Flow-through	Medium	0.67
	Large	1.00
Striped Bass-Food-size-Commercial-Flow-through	Medium	1.00
Salmon-Food-size-Other-Flow-through	Large	1.00

10.5.2 Sedimentation Basin

Sedimentation basins are the most common solids separation technique used to treat effluents in the United States. EPA based frequency factors for sedimentation basins used in the loading model for flow-through and recirculating CAAP facilities on the AAP screener survey results (Westat, 2002). The factors are presented in Table 10.5-2.

Table 10.5-2. Sedimentation Basin Frequency Factors

Species	*Model*	*Frequency Factor*
Trout-Food-size-Commercial-Flow-through	Medium	0.91
	Large	1.00
Trout-Food-size-State-Flow-through	Medium	1.00
	Large	1.00
Trout-Stockers-Commercial-Flow-through	Medium	1.00
Trout-Stockers-Federal-Flow-through	Medium	0.57
	Large	0.50
Trout-Stockers-State-Flow-through	Medium	0.91
	Large	1.00

Species	Model	Frequency Factor
Trout-Stockers-Other-Flow-through	Medium	1.00
	Large	1.00
Tilapia-Food-size-Commercial-Flow-through	Medium	0.67
	Large	1.00
Tilapia-Food-size-Commercial-Recirculating	Large	1.00
Striped Bass-Food-size-Commercial-Flow-through	Medium	1.00
Striped Bass-Food-size-Commercial-Recirculating	Large	1.00
Salmon-Food-size-Other-Flow-through	Large	1.00

10.5.3 BMP Plans

Solids management BMP plans are currently required of CAAP facilities operating in EPA's Region 10 (e.g., Idaho, Oregon, and Washington). EPA developed frequency factors for solids management BMP plans in flow-through, net pen, and recirculating CAAP facilities from the AAP screener survey (Westat, 2002). The factors are presented in Table 10.5-3.

Table 10.5-3. BMP Plan Frequency Factors

Species	Model	Frequency Factor
Trout-Food-size-Commercial-Flow-through	Medium	0.32
	Large	1.00
Trout-Food-size-State-Flow-through	Medium	0.00
	Large	0.00
Trout-Stockers-Commercial-Flow-through	Medium	0.60
Trout-Stockers-Federal-Flow-through	Medium	0.14
	Large	0.50
Trout-Stockers-State-Flow-through	Medium	0.02
	Large	0.00
Trout-Stockers-Other-Flow-through	Medium	1.00
	Large	1.00
Tilapia-Food-size-Commercial-Flow-through	Medium	0.00
	Large	0.00
Tilapia-Food-size-Commercial-Recirculating	Large	0.40
Striped Bass-Food-size-Commercial-Flow-through	Medium	0.00
Striped Bass-Food-size-Commercial-Recirculating	Large	0.00
Salmon-Food-size-Other-Flow-through	Large	0.00
Salmon-Food-size-Commercial-Net Pen	Large	0.13

10.5.4 Feed Management

Feed management is a commonly used practice in the CAAP facility industry because its benefits include both a cost savings for farms and reductions in pollutant loadings. EPA specified feed management as a management practice for net pen operations. The frequency factor EPA used in the loading model is based on the AAP screener survey results (Westat, 2002), and the factor is presented in Table 10.5-4.

Table 10.5-4. Feed Management Frequency Factor

Species	*Model*	*Frequency Factor*
Salmon-Food-size-Commercial-Net Pen	Large	0.88

The frequency factor for feed management was based on responses to the screener survey. Screener survey data indicated that about 88% of net pens are practicing feed management activities.

10.5.5 Drug and Chemical BMP Plan

EPA does not know of any facilities that have developed a drug and chemical BMP plan. Therefore, for the purpose of estimating pollutant loadings and removals, EPA assumed the frequency factors for a drug and chemical BMP plan in flow-through, net pen, and recirculating CAAP facilities were all zero.

10.5.6 Solids Polishing

Approximately 5% of the facilities responding to EPA's AAP screener survey reported using several different treatment technologies, including microscreen filters, for additional solids removal. EPA developed frequency factors for additional solids removal in flow-through and recirculating CAAP facilities from the AAP screener survey results (Westat, 2002), which are presented in Table 10.5-5.

Table 10.5-5. Solids Polishing Frequency Factors

Species	*Model*	*Frequency Factor*
Trout-Food-size-Commercial-Flow-through	Medium	0.09
	Large	0.00
Trout-Food-size-State-Flow-through	Medium	0.00
	Large	0.00
Trout-Stockers-Commercial-Flow-through	Medium	0.00
Trout-Stockers-Federal-Flow-through	Medium	0.00
	Large	0.00
Trout-Stockers-State-Flow-through	Medium	0.05
	Large	0.00
Trout-Stockers-Other-Flow-through	Medium	0.00

Species	Model	Frequency Factor
	Large	0.00
Tilapia-Food-size-Commercial-Flow-through	Medium	0.00
	Large	0.00
Tilapia-Food-size-Commercial-Recirculating	Large	0.40
Striped Bass-Food-size-Commercial-Flow-through	Medium	1.00
Striped Bass-Food-size-Commercial-Recirculating	Large	0.67
Salmon-Food-size-Other-Flow-through	Large	0.00

10.5.7 Net Pen Active Feed Monitoring

EPA developed a frequency factor for active feed monitoring in net pen CAAP facilities from the AAP screener survey results (Westat, 2002). The factor is presented in Table 10.5-6.

Table 10.5-6. Active Feed Monitoring Frequency Factor

Species	Model	Frequency Factor
Salmon-Food-size-Commercial-Net Pen	Large	0.38

10.6 LOADING MODEL STRUCTURE

10.6.1 Loading Removal Flow Chart

Figures 10.6-1 through 10.6-3 show how the pollutant loading models for flow-through, recirculating, and net pen production systems combine pollutant removal components to form the proposed regulatory options (for example, Option 1 for flow-through systems includes quiescent zones, sedimentation basins, and a BMP plan; Option 2 is the drug and chemical BMP plan; and Option 3 is solids polishing). Each flow chart also indicates how each treatment technology or BMP component loading is applied only to those facilities in the model facility group that do not currently have the treatment technology or BMP in place. Multiplying the number of facilities in the model facility group by each component-specific frequency factor makes this adjustment.

EPA's modeling approach estimates a total pollutant loading before and after each pollutant removal component. EPA can then determine pollutant loadings resulting from the individual component or across several linked components (one or more regulatory options). The modeling approach also allows EPA to determine pollutant removals for one or more proposed options by subtracting the estimated loading after a pollutant removal component from the estimated loading before the same component.

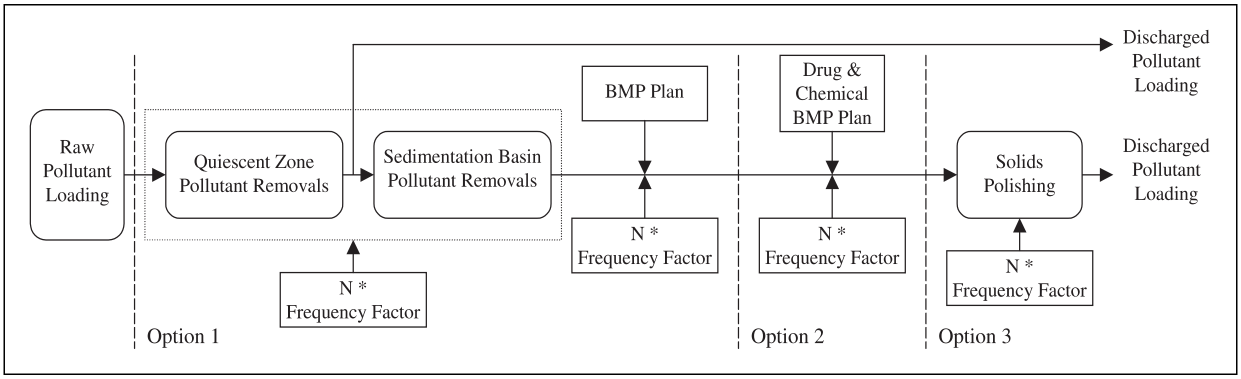


Figure 10.6-1. Schematic of Flow-through System Pollutant Loading Model

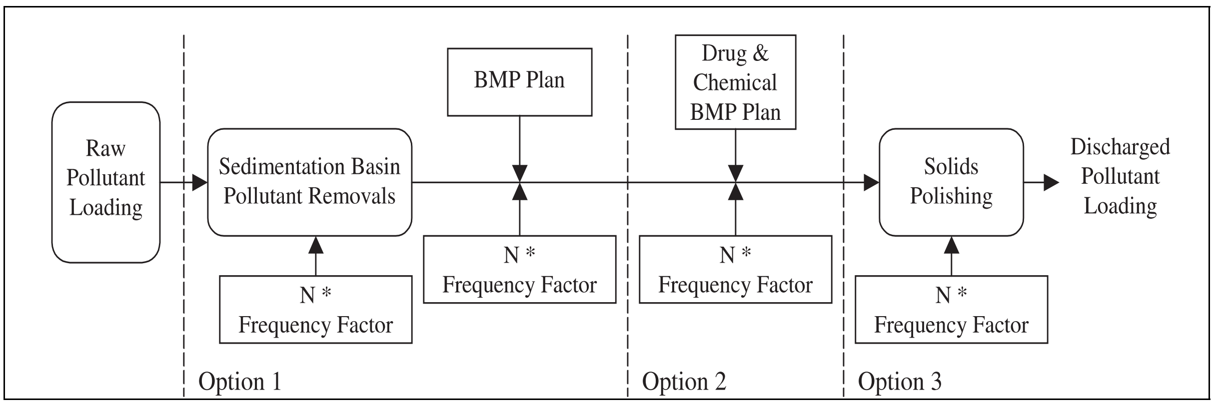


Figure 10.6-2. Schematic of Recirculating System Pollutant Loading Model

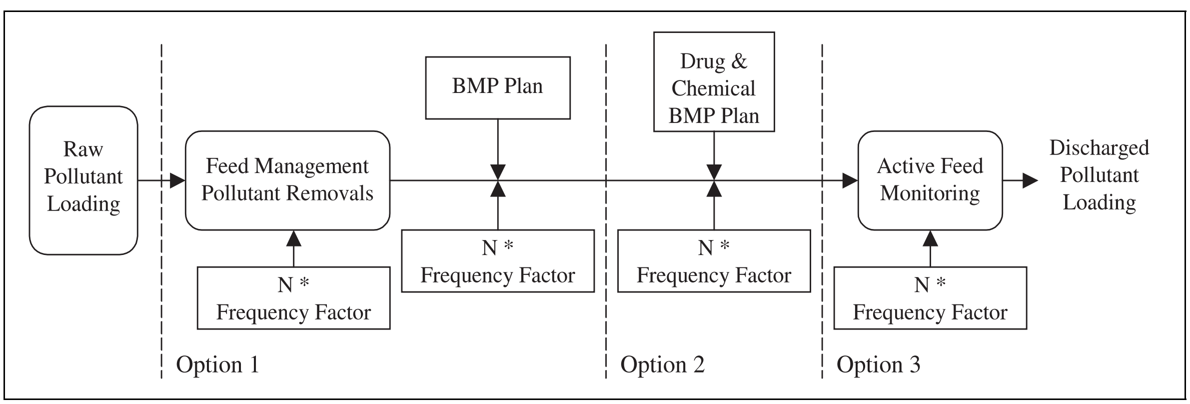


Figure 10.6-3. Schematic of Net Pen System Pollutant Loading Model

Baseline loadings for each pollutant are defined as the amount of pollutant currently being discharged by the facilities in a model facility group, including discharges from facilities that have existing treatment technologies in place. EPA calculated the baseline for a pollutant control technology as:

Component baseline loading = (raw pollutant loading * number of facilities) – baseline removal

Where:

Component baseline loading = pounds of a specific pollutant discharged prior to the application of a pollutant control technology, but includes control technologies currently in place at these facilities

Raw pollutant loading = pounds of raw pollutant

Number of Facilities = the count of facilities grouped as a model facility

Baseline Removal = pounds of a specific pollutant removed at the facilities, based on technologies currently in place

EPA calculated estimates of pollutant loadings for each pollutant removal component using the following general equation:

Component baseline pollutant removal = raw pollutant loading * technology removal rate number of facilities * frequency factor

Where:

Component baseline pollutant removal = pounds of pollutant currently removed from raw waste loadings

Raw pollutant loading = pounds of untreated pollutant from the facility

Technology removal rate = the percentage of pollutants removed by a treatment technology

Number of facilities = the count of facilities grouped as a model facility

Frequency factor = the percentage of facilities in the model facility group that have the specific treatment technology in place (see Tables 10.5-1 to 10.5-7)

The pollutant removal for a proposed option was calculated as follows:

Option pollutant removal = $[\text{input pollutant loading} * \text{technology removal} * \text{number of facilities} * (1 - \text{frequency factor})]_a + [\text{input pollutant loading} * \text{technology removal} * \text{number of facilities} * (1 - \text{frequency factor})]_b$

Where:

Option pollutant removal = pounds of a specific pollutant removed by the application of an option

Input pollutant loading = pounds of a pollutant prior to application of the option

Technology removal	=	percentage of pollutant removed by the treatment technology
Number of facilities	=	the count of facilities grouped as a model facility
Frequency factor	=	the percentage of facilities in the model facility group that have the specific treatment technology in place (see Tables 9.5-1 to 9.5-7)
a, b	=	each technology component

10.6.2 Loading Model Example

To illustrate the loading calculations, EPA has provided an example of one loading model facility. The example model facility is the medium-sized *federal-flow-through-trout-stockers* model. As shown in Table 10.3-1, this model facility represents seven facilities that produce between from 106,788 and 317,000 lb/yr, with an average production of 206,296 lb/yr.

For medium flow-through facilities, only regulatory Option 1 applies. The proposed Option 1 for flow-through systems includes quiescent zones, sedimentation basins, and a solids control BMP plan. The quiescent zone and sedimentation basin constitute a treatment control component. Note that the solids control BMP plan does not have any pollutant removal components, so the pollutant removal is zero. The schematic in Figure 10.6-4 shows how the components are grouped in Option 1.

EPA calculated baseline removal, baseline discharged loading, and the option removals using the equations shown in Section 10.6.1. The following shows the calculations.

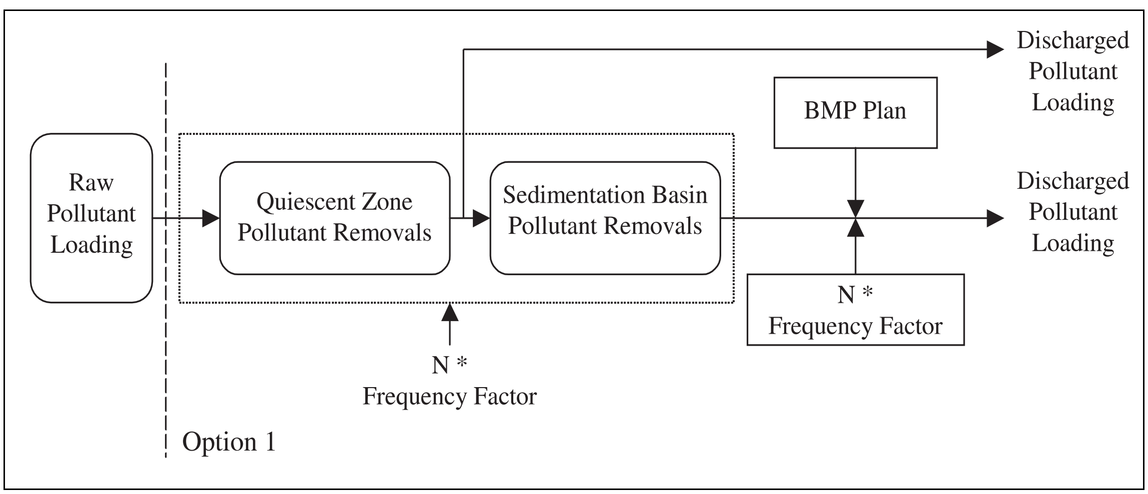


Figure 10.6-4. Schematic of Option 1 for Flow-through Systems

10.6.2.1 Estimation of Raw Loading

Because the raw pollutant loading is based on feed inputs (see Section 10.3-1 for more details), the loading model first calculates the annual feed input for the model facility using the facility annual production and feed conversion ratio. The equation for the annual feed input was:

Annual feed input = facility annual production * feed conversion ratio

Where:

Facility annual production = 208,296 lb of trout stockers

Feed conversion ratio = 1.4 lb of feed per pound of fish produced (Table 10.1-2)

Annual feed input = 208,296 lb of trout * 1.4 lb of feed per pound of trout

Annual feed input = 291,614 lb of feed

EPA calculated the raw pollutant loadings by multiplying the annual feed input by the feed- to-pollutant conversion ratio (see Table 10.1-3) for each pollutant modeled. The equation used for each pollutant was as follows:

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

Example:

Raw BOD loading = 291,614 lb of feed * 0.35 lb BOD per pound of feed

Raw BOD loading = 102,065 lb

The feed-to-pollutant conversion ratios and results of the raw pollutant loading calculations for the example model facility are shown in Table 10.6-1.

Table 10.6-1. Federal-Flow-through-Trout-Stockers Model Facility Raw Pollutant Loadings

Pollutant	***Feed-to-Pollutant Conversion Ratio***	***Raw Pollutant Loading (lb)***
BOD	0.35	102,065
TN	0.03	8,748
TP	0.005	1,458
TSS	0.3	87,484

10.6.2.2 Frequency Factors

EPA used frequency factors estimated from the AAP screener survey in the loading model to account for those existing *federal-flow-through-trout-stockers* facilities that already have the treatment technology (or equivalent) in place. The frequency factors for each component in Option 1 are presented in Table 10.6-2.

Table 10.6-2. Federal-Flow-through-Trout-Stockers Frequency Factors

Treatment Technology (source)	*Frequency Factor*	*(1 - Frequency Factor)*
Quiescent zone (Table 10.5-1)	0.57	0.43
Sedimentation basin (Table 10.5-2)	0.57	0.43
BMP plan (Table 10.5-3)	0.14	0.86

10.6.2.3 Baseline Removal

The baseline removal was calculated using the following equation:

Baseline removal = [raw loading * quiescent zone removal * sedimentation basin removal * N * frequency factor] + [loading_1 * BMP plan removal * N * frequency factor]

Where:

Raw loading = the untreated pollutant loading contained in the culture water from the model facility (Table 10.6-1)

Quiescent zone removal = the percentage of a specific pollutant removed by the quiescent zone (Table 10.6-3)

Sedimentation basin removal = the percentage of a specific pollutant removed by the sedimentation basin (Table 10.6-3)

Loading_1 = the loading from the first component

BMP plan removal = the percentage of a specific pollutant removed by the BMP plan (Table 10.6-3)

N = the number of facilities represented by the model facility

Frequency factor = the number of facilities indicating the use of primary settling operations in EPA's screener survey of the AAP industry (Table 10.6-2)

Because the BMP plan pollutant removals are zero for the pollutants EPA evaluated, the BMP plan component is eliminated from the calculations.

Example baseline removal calculation for BOD:

Baseline BOD removal = 102,065 lb BOD * 0.94 * 0.79 * 7 facilities * 0.57

<u>Baseline BOD removal = 302,416 lb</u>

Table 10.6-3. Summary of Quiescent Zone (QZ), Sedimentation Basin (SB), and BMP Plan (BMP) Removal Information for the Federal-Flow-through-Trout-Stockers Model Facility

Pollutant	*QZ Pollutant Removal Rate (%)*	*SB Pollutant Removal Rate (%)*	*BMP Pollutant Removal Rate (%)*
BOD	94.0	79.0	0
TN	8.5	7.1	0
TP	17.7	29.1	0
TSS	51.2	84.1	0

Table 10.6-4 shows the summary of baseline removals for remaining pollutants estimated for the *federal-flow-through-trout-stockers* model facility. EPA next calculated the baseline loading discharged:

Baseline loading discharged = (raw loading * N) – baseline removal

Where:

Raw loading = the untreated pollutant loading contained in the culture water from the model facility

N = the number of facilities represented by the model facility

Baseline removal = the removal obtained by the baseline treatment technologies

Example baseline loading discharged calculation for BOD:

Baseline loading discharged = (102,065 lb BOD * 7) – 304,416 lb BOD

<u>Baseline loading discharged = 412,039 lb BOD</u>

Table 10.6-4 summarizes the baseline discharge loadings for all of the pollutants for the *federal-flow-through-trout-stockers* model facility. The Option 1 removal is calculated using the following equation:

Option 1 removal = raw loading * quiescent zone removal * sedimentation basin removal * N * (1 - frequency factor)

Where:

Raw loading = the untreated pollutant loading contained in the culture water from the model facility

Quiescent zone removal = the percentage of a specific pollutant removed by the quiescent zone

Sedimentation basin removal = the percentage of a specific pollutant removed by the sedimentation basin

N	=	the number of facilities represented by the model facility
Frequency factor	=	the number of facilities indicating the use of primary settling operations in EPA's screener survey of the AAP industry

Example Option 1 removal calculation for BOD:

Option 1 removal = 102,065 lb BOD_5 * 0.94 * 0.79 * 7 * (1- 0.57)

Option 1 Removal = 228,138 lb

Table 10.6-4 summarizes the Option 1 removals for all of the pollutants for the *federal-flow-through-trout-stockers* model facility.

Table 10.6-4. Summary of Baseline Removals, Baseline Discharge Loading, and Option 1 Removals for the Federal-Flow-through-Trout-Stockers Model Facility

Pollutant	*Baseline Removal (lb)*	*Baseline Discharge Loading (lb)*	*Option 1 Pollutant Removals (lb)*
BOD	302,416	412,039	228,138
TN	210	61,029	158
TP	300	9,907	226
TSS	150,303	462,087	113,387

10.7 LOADING MODEL OUTPUT

EPA used the loading methodology described in this chapter to estimate the current discharge loadings of BOD, TN, TP, and TSS for the model facilities. EPA then applied the proposed regulatory options using the treatment trains illustrated in Section 10.6 to estimate pollutant reductions in these loadings, based on the option components for each system type. Table 10.7-1 presents the estimated total current discharge loadings for the model facilities. Table 10.7-2 presents the estimated total pollutant reductions for proposed regulatory Option 1. Table 10.7-3 presents the estimated total pollutant reductions for proposed regulatory Option 2. Table 10.7-4 presents the estimated total pollutant reductions for proposed regulatory Option 3. Table 10.7-5 presents the estimated current discharge loads for Alaska salmon facilities. Table 10.7-6 presents the estimated Option 1 total pollutant removals for Alaska salmon facilities. Table 10.7-7 presents the estimated Option 2 total pollutant removals for Alaska salmon facilities. Table 10.7-8 presents the estimated Option 3 total pollutant removals for Alaska salmon facilities.

Table 10.7-1. Estimated Current Discharge Loadings for the Model Facilities

Model Facility	*Size*	*Count*	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Trout-Food-size-Commercial-Flow-through	Medium	22	730,457	192,046	30,675	1,174,378
Trout-Food-size-Commercial-Flow-through	Large	8	2,521,683	834,670	132,745	4,781,439
Trout-Food-size-State-Flow-through	Medium	<5	123,510	40,882	6,502	234,191
Trout-Food-size-State-Flow-through	Large	<5	69,369	22,961	3,652	131,533
Trout-Stockers-Commercial-Flow-through	Medium	5	121,167	40,106	6,378	229,749
Trout-Stockers-Federal-Flow-through	Medium	7	412,039	61,029	9,907	462,087
Trout-Stockers-Federal-Flow-through	Large	<5	844,093	114,734	18,686	903,037
Trout-Stockers-State-Flow-through	Medium	44	1,567,218	412,041	65,815	2,519,665
Trout-Stockers-State-Flow-through	Large	<5	62,539	20,700	3,292	118,582
Trout-Stockers-Other-Flow-through	Medium	<5	48,090	15,918	2,532	91,185
Trout-Stockers-Other-Flow-through	Large	<5	60,540	20,039	3,187	114,793
Tilapia-Food-size Commercial-Flow-through	Medium	<5	182,192	30,955	5,001	221,136
Tilapia-Food-size Commercial-Flow-through	Large	<5	126,126	41,747	6,639	239,151
Tilapia-Food-size Commercial-Recirculating	Large	5	850,555	46,568	11,847	249,235
Striped Bass-Food-size Commercial-Flow-through	Medium	<5	15,549	5,147	819	29,483
Striped Bass-Food-size Commercial-Recirculating	Large	<5	1,727,510	81,475	23,911	267,451
Salmon-Food-size-Other-Flow-through	Large	<5	298,808	98,905	15,730	566,579
Salmon-Food-size-Commercial-Net pen	Large	8	7,432,432	637,066	106,178	6,370,656

Table 10.7-2. Estimated Option 1 Total Pollutant Removals

Model Facility	*Size*	*Count*	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Trout-Food-size-Commercial-Flow-through	Medium	22	150,568	105	149	74,834
Trout-Food-size-Commercial-Flow-through	Large	8	0	0	0	0
Trout-Food-size-State-Flow-through	Medium	<5	0	0	0	0
Trout-Food-size-State-Flow-through	Large	<5	0	0	0	0
Trout-Stockers-Commercial-Flow-through	Medium	5	0	0	0	0
Trout-Stockers-Federal-Flow-through	Medium	7	228,138	158	226	113,387
Trout-Stockers-Federal-Flow-through	Large	<5	498,507	346	494	247,763
Trout-Stockers-State-Flow-through	Medium	44	323,049	224	320	160,558
Trout-Stockers-State-Flow-through	Large	<5	0	0	0	0
Trout-Stockers-Other-Flow-through	Medium	<5	0	0	0	0
Trout-Stockers-Other-Flow-through	Large	<5	0	0	0	0
Tilapia-Food-size-Commercial-Flow-through	Medium	<5	88,858	62	88	44,163
Tilapia-Food-size-Commercial-Flow-through	Large	<5	0	0	0	0
Tilapia-Food-size-Commercial-Recirculating	Large	5	0	0	0	0
Striped Bass-Food-size-Commercial-Flow-through	Medium	<5	0	0	0	0
Striped Bass-Food-size-Commercial-Recirculating	Large	<5	0	0	0	0
Salmon-Food-size-Other-Flow-through	Large	<5	0	0	0	0
Salmon-Food-size-Commercial-Net pen	Large	8	661,700	56,717	9,453	567,172

Table 10.7-3. Estimated Option 2 Total Pollutant Removals

Model Facility	*Size*	*Count*	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Trout-Food-size-Commercial-Flow-through	Medium	22	150,568	105	149	74,834
Trout-Food-size-Commercial-Flow-through	Large	8	0	0	0	0
Trout-Food-size-State-Flow-through	Medium	<5	0	0	0	0
Trout-Food-size-State-Flow-through	Large	<5	0	0	0	0
Trout-Stockers-Commercial-Flow-through	Medium	5	0	0	0	0
Trout-Stockers-Federal-Flow-through	Medium	7	228,138	158	226	113,387
Trout-Stockers-Federal-Flow-through	Large	<5	498,507	346	494	247,763
Trout-Stockers-State-Flow-through	Medium	44	323,049	224	320	160,558
Trout-Stockers-State-Flow-through	Large	<5	0	0	0	0
Trout-Stockers-Other-Flow-through	Medium	<5	0	0	0	0
Trout-Stockers-Other-Flow-through	Large	<5	0	0	0	0
Tilapia-Food-size-Commercial-Flow-through	Medium	<5	88,858	62	88	44,163
Tilapia-Food-size-Commercial-Flow-through	Large	<5	0	0	0	0
Tilapia-Food-size-Commercial-Recirculating	Large	5	0	0	0	0
Striped Bass-Food-size-Commercial-Flow-through	Medium	<5	0	0	0	0
Striped Bass-Food-size-Commercial-Recirculating	Large	<5	0	0	0	0
Salmon-Food-size-Other-Flow-through	Large	<5	0	0	0	0
Salmon-Food-size-Commercial-Net pen	Large	8	661,700	56,717	9,453	567,172

Table 10.7-4. Estimated Option 3 Total Pollutant Removals

Model Facility	Size	Count	BOD (lb/yr)	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)
Trout-Food-size-Commercial-Flow-through	Medium	22	352,914	7,009	1,987	160,666
Trout-Food-size-Commercial-Flow-through	Large	8	966,939	32,995	8,782	410,160
Trout-Food-size-State-Flow-through	Medium	<5	47,360	1,616	430	20,089
Trout-Food-size-State-Flow-through	Large	<5	26,600	908	242	11,283
Trout-Stockers-Commercial-Flow-through	Medium	5	46,462	1,585	422	19,708
Trout-Stockers-Federal-Flow-through	Medium	7	298,655	2,565	866	143,299
Trout-Stockers-Federal-Flow-through	Large	<5	631,022	4,868	1,697	303,973
Trout-Stockers-State-Flow-through	Medium	44	776,271	15,690	4,436	352,808
Trout-Stockers-State-Flow-through	Large	<5	23,980	818	218	10,172
Trout-Stockers-Other-Flow-through	Medium	<5	18,440	629	167	7,822
Trout-Stockers-Other-Flow-through	Large	<5	23,214	792	211	9,847
Tilapia-Food-size-Commercial-Flow-through	Medium	<5	124,647	1,283	413	59,344
Tilapia-Food-size-Commercial-Flow-through	Large	<5	48,363	1,650	439	20,515
Tilapia-Food-size-Commercial-Recirculating	Large	5	296,318	11,646	3,418	38,230
Striped Bass-Food-size-Commercial-Flow-through	Medium	<5	0	0	0	0
Striped Bass-Food-size-Commercial-Recirculating	Large	<5	342,047	13,443	3,945	44,129
Salmon-Food-size-Other-Flow-through	Large	<5	114,578	3,910	1,041	48,602
Salmon-Food-size-Commercial-Net pen	Large	8	868,899	74,477	12,413	744,771

Table 10.7-5. Estimated Current Discharge Loadings for the Alaska Salmon Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Facility 1	51,322	4,399	733	43,990
Facility 2	98,515	8,444	1,407	84,442
Facility 3	100,028	8,574	1,429	85,738
Facility 4	70,774	6,066	1,011	60,663
Facility 5	66,400	5,691	949	56,914
Facility 6	197,722	16,948	2,825	169,476
Facility 7	73,903	6,335	1,056	63,345
Facility 8	61,603	5,280	880	52,802
Facility 9	75,152	6,442	1,074	64,416
Facility 10	101,748	8,721	1,454	87,213
Facility 11	482,745	41,378	6,896	413,781
Facility 12	57,152	4,899	816	48,987
Facility 13	179,355	15,373	2,562	153,733
Facility 14	119,826	10,271	1,712	102,708
Facility 15	279,837	23,986	3,998	239,860
Facility 16	71,094	6,094	1,016	60,937
Facility 17	108,922	9,336	1,556	93,362
Facility 18	122,523	10,502	1,750	105,020

Table 10.7-6. Estimated Option 1 Total Pollutant Removals for Alaska Salmon Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Facility 1	38,111	26	38	18,942
Facility 2	73,158	51	72	36,360
Facility 3	74,281	52	74	36,918
Facility 4	52,557	36	52	26,121
Facility 5	49,309	34	49	24,507
Facility 6	146,029	102	145	72,975
Facility 7	54,880	38	54	27,276
Facility 8	45,746	32	45	22,736
Facility 9	55,808	39	55	27,737
Facility 10	75,558	52	75	37,553
Facility 11	358,486	249	355	178,171
Facility 12	42,441	29	42	21,093
Facility 13	133,189	92	132	66,196
Facility 14	88,983	62	88	44,225
Facility 15	207,807	144	206	103,282
Facility 16	25,996	18	26	12,920
Facility 17	80,886	56	80	40,201
Facility 18	90,986	63	90	45,221

Table 10.7-7. Estimated Option 2 Total Pollutant Removals for Alaska Salmon Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Facility 1	38,111	26	38	18,942
Facility 2	73,158	51	72	36,360
Facility 3	74,281	52	74	36,918
Facility 4	52,557	36	52	26,121
Facility 5	49,309	34	49	24,507
Facility 6	146,029	102	145	72,975
Facility 7	54,880	38	54	27,276
Facility 8	45,746	32	45	22,736
Facility 9	55,808	39	55	27,737
Facility 10	75,558	52	75	37,553
Facility 11	358,486	249	355	178,171
Facility 12	42,441	29	42	21,093
Facility 13	133,189	92	132	66,196
Facility 14	88,983	62	88	44,225
Facility 15	207,807	144	206	103,282
Facility 16	25,996	18	26	12,920
Facility 17	80,886	56	80	40,201
Facility 18	90,986	63	90	45,221

Table 10.7-8. Estimated Option 3 Total Pollutant Removals for Alaska Salmon Facilities

Model Facility	*BOD (lb/yr)*	*TN (lb/yr)*	*TP (lb/yr)*	*TSS (lb/yr)*
Facility 1	43,177	199	84	21,090
Facility 2	82,881	383	161	40,485
Facility 3	84,154	388	163	41,106
Facility 4	59,542	275	116	29,084
Facility 5	55,862	258	108	27,287
Facility 6	166,344	768	323	81,253
Facility 7	62,174	287	121	30,370
Facility 8	51,826	239	101	25,315
Facility 9	63,225	292	123	30,883
Facility 10	85,601	395	166	41,813
Facility 11	406,133	1,875	788	198,382
Facility 12	48,082	222	93	23,486
Facility 13	150,891	697	293	73,705
Facility 14	100,810	465	196	49,242
Facility 15	235,426	1,087	457	114,998
Facility 16	29,451	136	57	14,386
Facility 17	91,636	423	178	44,761
Facility 18	103,079	476	200	50,350

10.8 References

AES (Aquacultural Engineering Society). 2001. *2001 AES Issues Forum*, November 11-14, 2001.

Boyd, C.E., and C.S. Tucker. 1995. Sustainability of Channel Catfish Farming. *World Aquaculture* 26(3):45-53.

Chen, S., D. Stechey, and R.F. Malone. 1994. Suspended Solids Control in Recirculating Aquaculture Systems. In *Aquaculture Water Reuse Systems: Engineering Design and Management*, ed. M.B. Timmons and T.M. Losordo, pp. 61-100. Elsevier, Amsterdam, The Netherlands.

Chen, S., S. Summerfelt, T. Losordo, and R. Malone. 2002. Recirculating Systems, Effluents and Treatments. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 119-140. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Engle. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source

Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Fish Farmer Magazine. 2002. Steps to Keep Fish Feed in Line with Public Concerns. <http://www.fishfarmer-magazine.com>. 14(June).

Hinshaw, J. 2002. North Carolina State University. Personal communication, February 20, 2002.

Hinshaw, J., and G. Fornshell. 2002. Effluents from Raceways. In *Aquaculture and the Environment in the United States*, ed. J. Tomasso, pp. 77-104. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Hochheimer, J. and H. Westers, 2002a. Technical Memorandum: Fish Growth, Feed Conversion, and Waste Production in Aquaculture. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and H. Westers. 2002b. Technical Memorandum: Flow-Through Systems. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. and H. Westers. 2002c. Technical Memorandum: Water Sources, Uses and Conservation Measures in Aquaculture. Tetra Tech, Inc., Fairfax, VA.

Hydromantis Inc. 2001. *CAPDET: For the Design and Cost Estimation of Wastewater Treatment Plants Version 1.0* [Computer program and manual]. Hydromantis, Inc. Consulting Engineers, Ontario, Canada.

IDEQ (Idaho Department of Environmental Quality). n.d. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

MacMillan, J. 2002. Clear Springs Foods, Inc., Buhl, ID. Personal communication, March 4, 2002.

McNair, M. 2001. *Alaska Salmon Enhancement Program: 2000 Annual Report*. Regional Information Report no. 5J01-01. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, AK.

MDA (Maryland Department of Agriculture). 1995. *State/Territory Permits and Regulations Impacting the Aquaculture Industry*. Maryland Department of Agriculture. <http://www.aquanic.org/publicat/state/md/perm.htm>. Accessed September 2001.

Metcalf and Eddy, Inc. 1991a. *Wastewater Engineering: Treatment and Disposal*. 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 220-240. McGraw Hill, NY.

Metcalf and Eddy, Inc. 1991b. *Wastewater Engineering: Treatment and Disposal*. 3d ed., revised by G. Tchobanoglous and F. Burton. pp. 689-690. McGraw Hill, NY.

Pierce. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source

Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Plemmons. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Rheault. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Rice. 2002. Comment from Small Entity Representative (SER) to the Small Business Advisory Review (SBAR) Panel on Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, U.S. Environmental Protection Agency, Washington, DC.

Tetra Tech, Inc. 2002a, August. Site visit report for MinAqua Fisheries Facility, Renville, MN.

Tetra Tech, Inc. 2002b, August. Site visit report for Heritage Salmon, Eastport, ME.

Tetra Tech, Inc. 2002c, August. Site visit report for Acadia Aquaculture, Mt. Desert, ME.

Tetra Tech, Inc. 2002d, August. Site visit report for Harrietta Hatchery, Harrietta, MI.

Tetra Tech, Inc. 2002e, August. Site visit report for Platte River Hatchery, Beulah, MI.

Tetra Tech, Inc. 2002f, August. Site visit report for Rushing Waters Fisheries, Palmyra, WI.

Tetra Tech, Inc. 2002g, August. Site visit report for Fins Technology, Turner Falls, MA.

Tetra Tech, Inc. 2002h, August. Site visit report for Lake Wheeler Road Agricultural Facility, Raleigh, NC.

Tetra Tech, Inc. 2002i. Alaska salmon conference call summary, February 2002.

USDA (U.S. Department of Agriculture). 2000. *The 1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agricultural Statistical Services, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002a. *Detailed Questionnaire for the Aquatic Animal Production Industry*. OMB Control no. 2040-0240. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002b. National Pollutant Discharge Elimination System Permit (NPDES) Permit no. ME0036234, issued to Acadia Aquaculture Inc. Signed February 21, 2002.

USEPA (U.S. Environmental Protection Agency). 2002c. National Pollutant Discharge Elimination System Permit no. WA0040878, issued to Washington State Department of Fish and Wildlife, South Sound Net Pens, Mason County. Signed March 20, 2002.

USEPA (U.S. Environmental Protection Agency). 2002d, August. Site visit report for Virginia Tech Aquaculture Center, Blacksburg, VA.

Westat. 2002. *AAP Screener Survey Production Range Report, Revision IV*. Westat, Inc., Rockville, MD.

CHAPTER 11
NON-WATER QUALITY ENVIRONMENTAL IMPACTS

Sections 304(b) and 306 of the Clean Water Act require EPA to consider non-water quality environmental impacts, including energy requirements, associated with effluent limitations guidelines and standards. In accordance with these requirements, EPA has considered the potential impacts of the proposed regulation on energy consumption, solid waste generation, and air emissions. The estimates of these impacts for the concentrated aquatic animal production (CAAP) industry are summarized in Sections 11.1, 11.2, and 11.3.

11.1 ENERGY

Additional energy requirements for the proposed rule are a result of electric motors needed to operate microscreen filters (a component of Option 3 for flow-through and recirculating systems) and video monitoring equipment for active feed management at net pen facilities. EPA proposed microscreen filters as a solids polishing treatment technology to remove additional TSS from the effluent prior to discharge. EPA proposed active feed management as a means to prevent uneaten feed from leaving the net pen. To calculate incremental energy consumption increases for the CAAP industry, EPA first determined the number of facilities that potentially would need to install new equipment, which are those flow-through facilities that annually produce more than 475,000 lb and recirculating and net pen system facilities that annually produce more than 100,000 lb. EPA used AAP screener survey data (Westat, 2002) and the 1998 Census of Aquaculture (USDA, 2000) to estimate the number of existing flow-through and recirculating system facilities without solids polishing currently in place. EPA used the same procedure to estimate the number of facilities without active feed management. Then, using the cost model (described in Chapter 9 of this document), EPA estimated the total number of microscreen filters and video monitors that would need to be installed to achieve the goal of the proposed rule. Finally, EPA used manufacturers' information to calculate the energy that would be required to operate microscreen filters and video monitors at those facilities without solids polishing currently in place. EPA estimated the energy requirements for the video monitoring equipment using a personal computer as a surrogate because manufacturer information on energy use was not available.

11.1.1 Estimating Increased Energy Requirements

Option 1

Option 1 proposes that flow-through and recirculating CAAP facilities implement primary settling treatment operations and develop a BMP plan. Primary settling treatment uses gravity settling, which requires no additional energy inputs. EPA assumed all facilities would use gravity flow to move water from quiescent zones (in flow-through systems) and other solids capture processes (in recirculating systems) to settling basins. EPA based this assumption on observed gravity flows from solids capture to primary settling in all of flow-through and recirculating systems seen during the site visits. Because gravity flow is assumed, no additional energy would be required for primary settling operations.

Option 1 would require net pen facilities to develop a best management practices (BMP) plan to minimize the addition of pollutants into the environment. Net pen systems are also subject to general requirements, which include the following BMPs:

- Develop and implement practices to minimize the potential escape of nonnative aquatic animals.
- A BMP plan to address net fouling and net cleaning; control of discharges of water containing blood associated with the transport or harvesting of fish or discharges of substances associated with pressure-washing nets.
- Practices to prevent the discharge of feed bags and other solid wastes, biocides or disinfectants used to clean equipment or nets, and materials containing or treated with tributyltin compounds.

Option 1 components for net pen facilities do not require additional energy; therefore, EPA assumed that there would be no increase in the energy used under regulatory Option 1 for any of the net pen facilities.

Option 2

Regulatory Option 2 for all facilities would require the reporting of the use of certain drugs and chemicals, which would not increase the energy requirements of production facilities.

Option 3

Energy requirements for flow-through and recirculating systems would be increased under Option 3 based on the installation of microscreen filters (solids polishing) as a treatment technology to meet the requirement of this regulatory option. Flow-through facilities that annually produce more than 475,000 lb and recirculating system facilities that annually produce more than 100,000 lb would be required to meet Option 3 standards under the proposed rule. Based on the AAP screener survey data (Westat, 2002) and the 1998 Census of Aquaculture (USDA, 2000), 40 CAAP facilities meet these definitions and require implementation of solids polishing.[1]

[1] To obtain estimates of the total number of facilities in the United States affected by the proposed rule, EPA used a comparison of the AAP screener survey results (Westat, 2002) and the 1998 Census of Aquaculture (USDA, 2000). Because the 1998 Census of Aquaculture represents only commercial facilities in the United States, EPA compared the number of facilities that responded to the AAP screener survey to the number of similar facilities in the 1998 Census of Aquaculture. EPA found the ratio to be about 2.5. For noncommercial facilities, EPA assumed that the AAP screener survey reflects a good approximation of the total number of facilities in the United States. Refer to Hochheimer (2002d) for more details.

EPA assumed the electricity requirements for the microscreen filter would be 5,782 kilowatt-hours (kWh) per year (Keaton Industries, 2002, personal communication). EPA used the following equation to determine the increase in energy requirements.

Energy increase = number of facilities x per facility energy increase

Where:

Number of facilities = the number of in-scope facilities that will have an energy increase

Per facility increase = the EPA-estimated per facility energy requirement increase

Energy increase = 40 facilities * 5,782 kWh

Energy increase = 231,280 kWh

EPA also estimated the cost of underwater video monitoring at net pen facilities. The Agency was not able to find manufacturers' data on the amount of electricity used in operating underwater video monitoring equipment, so EPA assumed the electrical usage would be similar to that for a personal computer and monitor, which is about 7.8 amps at 120 volts. EPA assumed that the feeding time per net pen is about 10 min per feeding. The fish are fed once per day for 312 d/yr (6 feeding days per week). The model facility has 12 net pens. EPA used the following equations to estimate the increase in energy (Hochheimer, 2002b).

Watts = amps * volts = 7.8 amps * 120 volts = 936 watts

Daily energy use (kWh) = (watts/1,000) * (10 min/feeding * 1 h/60 min) * 1 feeding per day

Daily energy use = (936 W/1,000) * (10 min/feeding * 1 h/60 min) * 1 feeding per day = 0.156 kWh

Annual energy increase (kWh/yr) = kWh * 312 d = 0.156 kWh * 312 d = 48.7 kWh per net pen

Total energy increase per facility = number of net pens * 48.7 kWh per net pen

Total energy increase per facility = 12 net pens * 48.7 kWh per net pen = 584.4 kWh

Total industry energy increase = 12 facilities * 584.4 kWh = 7,013 kWh

11.1.2 Energy Summary

EPA estimates that implementing this rule will result in a net increase in energy consumption for some CAAP facilities. The incremental increase is based on electricity used to operate microscreen filters or video monitoring equipment at facilities that are not currently operating wastewater treatment equipment comparable to the proposed regulatory options.

EPA extrapolated the energy consumption increases to represent the entire CAAP industry using estimates of the number of facilities and frequency factors (as discussed in Chapter 9). The total incremental energy increase for microscreens and video monitoring equipment at CAAP facilities as a result of this regulation would be 238,293 kWh/yr.

Site-specific information is needed to assess the impact of additional energy required for solids polishing at flow-through and recirculating facilities and video monitoring at net pen facilities. EPA used estimates of electrical costs from published enterprise budgets to provide a comparison of the existing electrical requirements and the added electrical requirements of microscreen filters at flow-through and recirculating system facilities (Hochheimer, 2002a). Hinshaw et al. (1990) estimated annual electrical requirements at about 7,357 kWh for a 100,000-lb production facility in North Carolina. San et al. (2001) estimated electrical requirements of about 1,662 kWh for a facility of similar size in West Virginia. Dunning et al. (1998) estimated an annual electrical requirement of 2.3 kWh per pound of fish produced at recirculating system facilities. Thus, for average-size flow-through facilities (annual production of 1,841,889 lb/yr; Westat, 2002), the range of existing energy use is from 30,612 to 135,507 kWh. For recirculating systems (annual production of 681,022 lb/yr; Westat, 2002), the existing electrical usage estimate is about 1,566,351 kWh. Thus, the average flow-through facility would increase its electrical use by about 4.3% to 18.9%, and the average recirculating system would increase its use by about 0.4%.

Site-specific information is also needed to accurately assess the impact of additional energy required for active feed monitoring at net pen facilities. EPA was not able to find estimates of current energy usage at net pen facilities. The estimated increase in energy usage at a facility was about 584 kWh, which is not expected to be a significant increase with respect to the total energy requirements at these facilities.

EPA does not expect any adverse impacts to occur as a result of the small energy requirements for the proposed regulation.

11.2 SOLID WASTE

The proposed treatment technologies will generate solid wastes. Solid wastes include sludge from sedimentation basins (primary settling) and from solids polishing technologies such as microscreen filters. EPA assumed all solid wastes generated by the CAAP industry to be nonhazardous. Federal and state regulations require CAAP facilities to manage solids to prevent release to the environment.

11.2.1 Sludge Characterization

Chen et al. (1996) provide a comprehensive review of the treament and characteristics of CAAP sludge. Table 11.2-1 shows the characteristics of recirculating system sludge captured from solids filter backwash allowed to settle for 30 min. Although representing only one study, these data represent a process similar to EPA's Option 1.

Table 11.2-1. Characterization of CAAP Sludge

Parameter	*CAAP Sludge*		
	Range	*Mean*	*Standard Deviation*
TS (%)	1.4–2.6	1.8	0.35
TVS (% of TS)	74.6–86.6	82.2	4.1
BOD_5 (mg/L)	1,588–3,867	2,756.0	212.0
TAN (N, mg/L)	6.8–25.6	18.3	6.1
TKN (N, % of TS)	3.7–4.7	4.0	0.5
TP (P, % of TS)	0.6–2.6	1.3	0.7
pH	6.0–7.2	6.7	0.4

Source: Reported in Chen et al., 1996.

Naylor et al. (1999) compared fish manure with manure from beef, poultry, and swine. Overall, the nutrient composition of trout manure is similar to that of other animal manures (Table 11.2-2). Like livestock manure, the composition of fish manure is also highly variable due to differences in animal, age, feed, manure handling, and storage conditions.

Table 11.2-2. Rainbow Trout Manure Compared to Beef, Poultry, and Swine Manures (Presented as Ranges on a Dry Weight Basis)

Element	*Fish*	*Beef*	*Poultry*	*Swine*
Nitrogen (%)	2.04–3.94	1.90–7.8	1.3–14.5	0.6–10.0
Phosphorus (%)	0.56–4.67	0.41–2.6	0.15–4.0	0.45–6.5
Potassium (%)	0.06–0.23	0.44–4.2	0.55–5.4	0.45–6.3
Calcium (%)	3.0–11.2	0.53–5.0	0.71–14.9	0.4–6.4
Magnesium (%)	0.04–1.93	0.29–0.56	0.3–1.3	0.09–1.34

Source: Naylor et al., 1999.

11.2.2 Estimating Increased Sludge Collection

EPA estimated the incremental sludge generation from the treatment options similarly to the way the Agency estimated the incremental energy consumption. EPA assumed that sludge generation would not increase at facilities with the required technology already in place. EPA used the loadings models (see Chapter 9) to estimate the incremental sludge generation rates for facilities that do not have these technologies in place.

By using reported production values, EPA estimated the total amount of solids collected and disposed of for CAAP facilities. The total estimated amount of solids currently collected by all in-scope facilities before regulation is shown in the first column of Table 11.2-3.

EPA also estimated the incremental amounts of solids collected for disposal by CAAP facilities after implementation of the proposed regulatory options. They are shown in

Table 11.2-3. The proposed regulation requires all flow-through and recirculating CAAP facilities to meet the requirements contained in Option 1. Net pen systems do not collect solids. Under general requirements for net pen systems, however, facilities must control discharges of solid waste and prevent discharge of water used for transport, which might contain blood and other wastes. Regulatory Option 2 does not have additional solids removal for any of the facility groupings. Large flow-through and recirculating facilities collect additional solids under Option 3, and the estimated amounts are shown in Table 11.2-3.

Table 11.2-3. Estimated Solids Collection

Facility Group	*Current Solids Collection (lb/yr)*	*Option 1 Incremental Solids Collection (lb/yr)*	*Option 2 Incremental Solids Collection (lb/yr)*	*Option 3 Incremental Solids Collection (lb/yr)*
State-Federal-Other-Medium-Flow-through	2,719,134	269,270	0	0
Commercial-Medium-Flow-through	3,060,809	207,524	0	0
State-Federal-Other-Large-Flow-through	1,673,874	379,782	0	424,214
Commercial-Large-Flow-through	10,562,685	0	0	1,198,193
Large-Recirculating	5,956,215	0	0	165,787
Total	23,972,717	856,576	0	1,788,194

EPA assumed that collected solids would be land-applied as fertilizer at agronomic rates and therefore does not expect any adverse impacts due to solid waste to occur as a result of the proposed regulation.

11.3 AIR EMISSIONS

Potential sources of air emissions from CAAP facilities include primary settling operations (e.g., settling basins and lagoons) and the land application of manure.

11.3.1 Air Emissions from Primary Settling Operations

EPA assumed that the additional air emissions from primary settling operations would be minimal. Only about 10% of in-scope flow-through and recirculating CAAP facilities (estimated from the AAP screener survey data (Westat, 2002) and the 1998 Census of Aquaculture (USDA, 2000)) would require the addition of primary settling to meet Option 1 requirements. Primary settling treatment technologies store collected solids below the surface of the water, reducing their exposure to the atmosphere. Air emissions primarily result from exposure of collected solids to air (Battye et al., 1994). For ammonia that volatilizes from aquatic animal manures, the pH of the water in the sedimentation basin covering the settled solids reduces the rate of volatilization because at lower pH levels most of the ammonia in the water is in an ionized form. At pH levels from 6.5 to 7.5, which are typical of sampled sedimentation basins, and at a temperature of 86 °F (a worst-case situation), the percentage of ammonia in solution (un-ionized) ranges from 0.26% to 2.48%. At typical total ammonia levels found in the sampling of sedimentation basins (about 0.4 to 3.69 mg/L), the concentration of un-ionized ammonia ranges from 0.0010 to 0.0915 mg/L. The air-to-water interface is also relatively low in sedimentation basins (Hochheimer, 2002c)

11.3.2 Air Emissions from Land Application Activities

The CAAP sludge emits pollutants when it is spread on land for its fertilizer value. Air emissions are primarily generated from the volatilization of ammonia at the point the material is applied to land (Anderson, 2000). Additional emissions of nitrous oxide are liberated from agricultural soils when nitrogen applied to the soil undergoes nitrification and denitrification. Loss through denitrification depends on the oxygen levels of the soil to which manure is applied. Low oxygen levels, resulting from wet, compacted, or warm soil, increase the amount of nitrate-nitrogen released to the air as nitrogen gas or nitrous oxide (OSUE, 2000). A study by Sharpe and Harper (1997), which compared losses of ammonia and nitrous oxide from the sprinkler irrigation of swine effluent, concluded that ammonia emissions made a larger contribution to airborne nitrogen losses. Data for the CAAP industry are insufficient to quantify air emission impacts from the land application of manure; therefore, this analysis uses available information from similar industries and focuses on the volatilization of nitrogen as ammonia. The emission of other constituents is expected to be less significant.

11.3.2.1 Application Rate

The application rate affects the volatilization rate if the amount of manure applied causes significant buildup of material on the field surface, causing a mulching effect. For the purposes of this analysis EPA assumed that the CAAP industry applies manure at agronomic rates or lower. Applying at agronomic rates, CAAP facilities do not apply enough waste under the proposed options to cause mulching.

11.3.2.2 Application Method

Significant differences in the volatilization rate of ammonia result from the method used to apply manure (see Table 11.3-1). When manure is sprinkler-irrigated, a greater surface area from which the ammonia can volatilize is available. Manure application methods practiced by the CAAP industry include irrigation, surface application, and subsurface injection. EPA observed that applying solids as fertilizer for cropland at agronomic rates is a common industry practice. When agricultural land is adjacent to a CAAP facility, solids can be vacuumed directly from quiescent zones into a sprinkler system that land-applies the biosolids and water (IDEQ, n.d.). EPA assumed this regulation would not change the method of land application used by any CAAP facilities. Based on this assumption, no significant change in the rate at which ammonia volatilizes is expected.

Table 11.3-1. Percent of Nitrogen Volatilizing as Ammonia from Land Application

Application Method		*Percent Loss* [a]
Surface application	Broadcast (solid)	15–30
	Broadcast (liquid)	10–25
Subsurface injection	Broadcast (solid, immediate incorporation)	1–5
	Broadcast (liquid, immediate incorporation)	1–5
	Knifing (liquid)	0–2
Irrigation	Sprinkler irrigation (liquid)	15–40

Source: MWPS, 1983.
[a] Percent of nitrogen applied that is lost within 4 days of application.

11.3.2.3 Quantity of Animal Waste

The movement of waste off-site changes the location of the ammonia released but not the quantity released. Although the proposed options do not require land application of manure, the options do increase the amount of solid waste collected from CAAP facilities. Land application is a common solid waste disposal method in the CAAP industry; therefore, the amount of ammonia released as air emissions would be expected to increase as the quantity of waste applied to cropland increases.

11.3.2.4 Calculation of Emissions

EPA estimated the increase in ammonia emissions resulting from the implementation of each proposed regulatory option. The Agency assumed the ammonia content of solid waste from CAAP facilities was approximately 2.83% (Naylor et al., 1999). A factor of 30% was chosen as a conservative estimate of losses from land application activities. Table 11.3-2 indicates the current estimated ammonia volatilization resulting from land application of solids by CAAP facilities. Tables 11.3-3 and 11.3-4 indicate the estimated incremental increase in ammonia volatilization resulting from regulatory Option 1 and Option 3.

EPA calculated the ammonia content of the solid waste using the following equation:

Ammonia content = solid waste volume * 2.83%

Where:

Solid waste volume = the amount of solids collected by CAAP facilities

The following equation was used to calculate the ammonia volatilized during application:

Ammonia volatilization = ammonia content * 30.0%

Where:

Ammonia content = the amount of ammonia contained in solids from CAAP facilities

Table 11.3-2. Baseline Ammonia Volatilization

Facility Group	*Current Solids Collection (lb/yr)*	*Ammonia Content (lb/yr)*	*Ammonia Volatilization (lb/yr)*
State-Federal-Medium-Flow-through	2,719,134	76,951	23,085
Commercial-Medium-Flow-through	3,060,809	86,621	25,986
State-Federal-Large-Flow-through	1,673,874	47,371	14,211
Commercial-Large-Flow-through	10,562,685	298,924	89,677
Large-Recirculating	5,956,215	168,561	50,568

Table 11.3-3. Incremental Increases in Ammonia Volatilization Under Option 1

Facility Group	*Option 1 Solids Collection Increase (lb/yr)*	*Ammonia Applied (lb/yr)*	*Ammonia Volatilization (lb/yr)*
State-Federal-Medium-Flow-through	269,270	7,620	2,286
Commercial-Medium-Flow-through	207,524	5,873	1,762
State-Federal-Large-Flow-through	379,782	10,748	3,224
Commercial-Large-Flow-through	0	0	0
Large-Recirculating	0	0	0

Table 11.3-4. Incremental Increases in Ammonia Volatilization Under Option 3

Facility Group	*Option 3 Solids Collection Increase (lb/yr)*	*Ammonia Applied (lb/yr)*	*Ammonia Volatilization (lb/yr)*
State-Federal-Medium-Flow-through	0	0	0
Commercial-Medium-Flow-through	0	0	0
State-Federal-Large-Flow-through	424,214	12,005	3,602
Commercial-Large-Flow-through	1,198,193	33,909	10,173
Large-Recirculating	165,787	4,692	1,408

EPA does not expect any adverse air impacts to occur as a result of the proposed regulation.

11.4 REFERENCES

Anderson, 2000. Chapter 13 in *Animal Manure as a Plant Resource*. <http://www.agcom.purdue.edu/agcom/pubs/ID/ID-101.htm>.

Battye, R., W. Battye, C. Overcash, and S. Fudge. 1994. *Developments and Selection of Ammonia Emission Factors*. Final Report. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Chen, S., Z. Ning, and R.F. Malone. 1996. Aquaculture Sludge Treatment Using an Anaerobic and Facultative Lagoon System. In *Successes and Failures in Commercial Recirculating Aquaculture*, vol. II. pp. 421-430. National Regional Agricultural Engineering Service, Ithaca, NY.

Dunning, R.D., T.M. Losordo, and A.O. Hobbs. 1998. *The Economics of Recirculating Tank Systems: Spreadsheet for Individual Analysis*. SRAC publication no. 456. Southern Regional Aquaculture Center, Stoneville, MS.

Hinshaw, J.M., L.E. Rogers, and J.E. Easley. 1990. *Budgets for Trout Production: Estimated Costs and Returns for Trout Farming in the South*. SRAC publication no. 221. Southern Regional Aquaculture Center, Stoneville, MS.

Hochheimer, J. 2002a. Technical Memorandum: Energy Requirements, AAP Development Document. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. 2002b. Technical Memorandum: Video Monitoring Equipment Electrical Use. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. 2002c. Technical Memorandum: Ammonia Volatilization Calculations for Non-Water Quality Impacts. Tetra Tech, Inc., Fairfax, VA.

Hochheimer, J. 2002d. Technical Memorandum: Screener Conversion Factor. Tetra Tech, Inc., Fairfax, VA.

IDEQ (Idaho Department of Environmental Quality). n.d. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Environmental Quality. <http://www2.state.id.us/deq/water/gw/Aquaculture_Guidelines.pdf>. Accessed August 2002.

Keaton Industries. 2002. Personal communication, July 22, 2002.

MWPS (Midwest Plan Service). 1983. *Midwest Plan Service: Livestock Waste Facilities Handbook*. 2d ed. Iowa State University, Ames, IA.

Naylor, S.J., R.D. Moccia, and G.M. Durant. 1999. The Chemical Composition of Settleable Solid Fish Waste (Manure) from Commercial Rainbow Trout Farms in Ontario, Canada. *North American Journal of Aquaculture* 61:21-26.

OSUE (Ohio State University Extension). 2000. *Selecting Forms of Nitrogen Fertilizer*. <http://www2.ag.ohio-state.edu/~ohioline/agf-fact/0205.html> Ohio State University Extension. Accessed July 2002.

San, N.N., D. Miller, G. D'Souza, D.K. Smither, and K. Semmens. 2001. *West Virginia Trout Enterprise Budgets*. Aquaculture Information Series publication no. AQ01-1. West Virginia University Extension Service, Morgantown, WV.

Sharpe, R.R., and L.A. Harper. 1997. Ammonia and Nitrous Oxide Emissions from Sprinkler Irrigation Applications of Swine Effluent. *Journal of Environmental Quality* 26:1703-1706.

USDA (U.S. Department of Agriculture). 2000. *The 1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agriculture Statistics Service, Washington, DC.

Westat. 2002. *AAP Screener Survey Production Range Report*, Revision IV. Westat, Inc., Rockville, MD.

Abbreviations and Acronyms

AAP	aquatic animal production
ADEM	Alabama Department of Environmental Management
ADFG	Alaska Department of Fish and Game
AETF	Aquaculture Effluents Task Force (JSA)
AFS	American Fisheries Society
APHIS	Animal and Planet Health Inspection Service (USDA)
BAT	Best Available Technology Economically Achievable
BCT	Best Control Technology for Conventional Pollutants
BGD	bacterial gill disease
BMPs	best management practices
BOD	biochemical oxygen demand
BOD_5	biochemical oxygen demand measured over a 5-day period
BPJ	best professional judgment
BPT	Best Practicable Control Technology
CAAP	concentrated aquatic animal production
CAPDET	Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment
CBI	Confidential Business Information
C-BOD_5	carbonaceous biochemical oxygen demand measured over a 5-day period
CCVD	channel catfish virus disease
CFR	Code of Federal Regulations
CITES	Convention on International Trade of Endangered Species of Wild Fauna and Flora
COD	chemical oxygen demand

CTSA	Center for Tropical and Subtropical Aquaculture
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DMR	Discharge Monitoring Report
DO	dissolved oxygen
ELGs	Effluent Limitations Guidelines
ERM	enteric redmouth
ERS	Economic Research Service (USDA)
ESC	enteric septicemia in catfish
FAO	Food and Agriculture Organization (United Nations)
FCR	feed conversion ratio
FDA	Food and Drug Administration
FDACS	Florida Department of Agriculture and Consumer Services
FDF	fundamentally different factor
FFS	full-flow settling
FR	Federal Register
FTE	full-time equivalent
HACCP	Hazard Analysis and Critical Control Points
HCG	human chorionic gonadotropin
ICR	Information Collection Request
IDEQ	Idaho Division of Environmental Quality
IHHN	infectious hypodermal and hematopoietic necrosis
INAD	investigational new animal drug
IPNV	infectious pancreatic necrosis virus
IRFA	Initial Regulatory Flexibility Analysis
ISA	infectious salmon anemia
JSA	Joint Subcommittee on Aquaculture
LTA	long-term average

LRP	low regulatory priority
MAS	motile aeromonas septicemia
MDA	Maryland Department of Agriculture
MEPA	Massachusetts Environmental Policy Act
ML	minimum limit
MPRSA	Marine Protection Research and Sanctuaries Act
NAHMS	National Animal Health Monitoring System
NAICS	North American Industry Classification System
NASAC	National Association of State Aquaculture Coordinators
NASS	National Agricultural Statistics Service (USDA)
NMFS	National Marine Fisheries Service (Department of Commerce)
NOAA	National Oceanic and Atmospheric Administration (Department of Commerce)
NODA	Notice of Data Availability
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service (USDA)
NRDC	Natural Resources Defense Council
NSPS	New Source Performance Standards
NSTC	National Science and Technology Council
NTTA	National Technology Transfer and Advancement Act
NTU	nephelometric turbidity units
NWPCAM	National Water Pollution Control Assessment Model
NWQI	non-water quality impact
OLS	offline settling
O&M	operation and maintenance
OMB	Office of Management and Budget
PCB	polychlorinated biphenyl
PCS	Permit Compliance System
PGD	proliferative gill disease

POC	Pollutants of Concern
POTW	publicly owned treatment works
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QZ	quiescent zone
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act of 1976
RFA	Regulatory Flexibility Act
RHA	Rivers and Harbors Act
SAL	Special Activity License
SAP	Sampling and Analysis Procedures
SBA	Small Business Administration
SBAR	Small Business Advocacy Review Panel
SBREFA	Small Business Regulatory Enforcement Fairness Act of 1996
SCC	Sample Control Center
SEQR	State Environmental Quality Review
SER	Small Entity Representative
SIC	Standard Industrial Classification
SIU	Significant Industrial User
SPF	specific pathogen-free
SPR	specific pathogen-resistant
SRAC	Southern Regional Aquaculture Center
SS	settleable solids
TAN	total ammonia nitrogen
TBT	tributyltin
TCI	The Catfish Institute

TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TL	total length
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TS	total solids
TSS	total suspended solids
TSV	taura syndrome virus
TVS	total volatile solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey (Department of the Interior)
USFWS	United States Fish and Wildlife Service (Department of the Interior)
USTFA	United States Trout Farmer's Association
UV	ultraviolet
VDEQ	Virginia Department of Environmental Quality
VHS	viral hemorrhagic septicemia
WDF	Washington Department of Fisheries
WDOE	Washington Department of Ecology
WSSV	white spot syndrome virus
YHV	yellow head virus

GLOSSARY

Aeration: The process of bringing air into contact with a liquid by one or more of the following methods: (1) spraying the liquid into the air, (2) bubbling air through the liquid, and (3) agitating the liquid to promote absorption of oxygen through the air-liquid interface.

Aerobic: Having or occurring in the presence of free oxygen.

Agronomic rates: The land application of animal wastes at rates of application that provide the crop or forage growth with needed nutrients for optimum health and growth.

Algal bloom: Sudden spurts of algal growth, which can affect water quality adversely and indicate potentially hazardous changes in local water chemistry.

Aliquot: A measured portion of a sample taken for analysis. One or more aliquots make up a sample.

Anadromous: Describes fish born in freshwater, descending into the sea to grow to maturity, and then returning to spawn in freshwater rivers and streams.

Anaerobic: Characterized by the absence of molecular oxygen, or capable of living and growing in the absence of oxygen, such as *anaerobic bacteria*.

Analytes: Chemical constituents analyzed as part of the aquatic animal production industry sampling episodes.

Androgens: Hormones used to invert the sex of female fry.

Antifoulant: Substance used to retard the growth of marine organisms on an object placed in the underwater marine environment.

Aquaculture: The production of aquatic plants and animals under controlled or semicontrolled conditions.

Aquatic animal pathogen: An organism that can cause disease outbreaks in aquatic animals.

Aquatic animal production: The production of aquatic animals under controlled or semicontrolled conditions.

Baffle: A device (such as a plate, wall, or screen) to deflect, check, or regulate the flow of water in a raceway.

Benthic monitoring: Monitoring conducted to ensure that degradation is not occurring under or around net pens.

Best Available Technology Economically Achievable (BAT): Technology-based standard established by the Clean Water Act (CWA) as the most appropriate means available on a national basis for controlling the direct discharge of toxic and nonconventional pollutants to navigable waters. BAT effluent limitations guidelines, in general, represent the best existing performance of treatment technologies that are economically achievable within an industrial point source category or subcategory.

Best Control Technology for Conventional Pollutants (BCT): Technology-based standard for the discharge from existing industrial point sources of conventional pollutants including BOD, TSS, fecal coliform, pH, oil and grease. The BCT is established in light of a two-part "cost reasonableness" test, which compares the cost for an industry to reduce its pollutant discharge with the cost to a POTW for similar levels of reduction of a pollutant loading. The second test examines the cost-effectiveness of additional industrial treatment beyond BPT. EPA must find limits, which are reasonable under both tests before establishing them as BCT.

Best management practice (BMP): A practice or combination of practices found to be the most effective, practicable (including economic and institutional considerations) means of preventing or reducing the amount of pollution generated.

Best Practicable Control Technology Currently Available (BPT): The first level of technology-based standards established by the CWA to control pollutants discharged to waters of the United States. BPT effluent limitations guidelines are generally based on the average of the best existing performance by plants within an industrial category or subcategory.

Biochemical oxygen demand (BOD): An indirect measure of the concentration of biodegradable substances present in an aqueous solution. Determined by the amount of dissolved oxygen required for the aerobic degradation of the organic matter at 20 °C. BOD_5 refers to the oxygen demand for the initial 5 days of the degradation process.

Biocide: Products added to other materials (typically liquids) to protect the other material from biological infestation and growth. Examples are well drilling fluid additives, cooling tower algaecides, products called slimicides, etc. The size of the biological organism a biocide controls is usually limited to single cell organisms and microscopic multicell organisms.

Biomass: All of the living material in a given area.

Bivalves: Animals characterized by a soft body enclosed by two hard shells or valves. The valves are attached at a hinge and are held shut by a strong muscle.

Brackish water: Mixed fresh and salt water.

Broodstock: A sexually mature group of a cultured species maintained solely for the production of eggs.

Byssal threads: Strong threadlike material used by some mussels to attach to their surroundings.

Carotenoids: Yellow or red pigments found in animal fat and some plants.

Chemical: Any substance that is added to a concentrated aquatic animal production facility to maintain or restore water quality for aquatic animal production and that might be discharged to waters of the United States.

Chemical oxygen demand (COD): A measure of the oxygen equivalent of the portion of organic matter that can be oxidized by a strong chemical oxidizing agent. This measure gives a better estimate of the total oxygen demand (as compared to BOD).

Clean Water Act (CWA): The Clean Water Act is an act passed by the U.S. Congress to control water pollution. It was formerly referred to as the Federal Water Pollution Control Act of 1972 or Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), 33 U.S.C. 1251 et. seq., as amended by: Public Law 96-483; Public Law 97-117; Public Laws 95-217, 97-117, 97-440, and 100-04.

Cohort: A group of like-species aquatic animals born in the same year.

Concentrated aquatic animal production (CAAP) facility: A hatchery, fish farm, or other facility that contains, grows, or holds aquatic animals in either of the following categories, or that the Director[1] designates as such on a case-by-case basis, and must apply for a National Pollutant Discharge Elimination System permit:

A. Coldwater fish species or other coldwater aquatic animals including, but not limited to, the Salmonidae family of fish (e.g., trout and salmon) in ponds, raceways, or other similar structures that discharge at least 30 days per year but does not include (1) facilities that produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year and (2) facilities that feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding.

B. Warmwater fish species or other warmwater aquatic animals including, but not limited to, the Ameiuridae, Cetrachidae, and the Cyprinidae families of fish (e.g., respectively, catfish, sunfish, and minnows) in ponds, raceways, or similar structures that discharge at least 30 days per year, but does not include (1) closed ponds that discharge only during periods of excess runoff or (2) facilities that produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) of aquatic animals per year.

[1] The Regional Administrator or State Director, as the context requires, or an authorized representative. When there is no approved state program, and there is an EPA administered program, Director means the Regional Administrator. When there is an approved state program, "Director" normally means the State Director.

Confidential Business Information (CBI): Any information in any form received by EPA or its approved contractors from any person, firm, partnership, corporation, association, or local, state, or federal agency, or foreign government, that contains trade secrets or commercial or financial information; has been claimed as CBI by the person submitting it; and has not been determined to be non-CBI under the procedures in 40 CFR Part 2.

Consent decree: A legal document, approved by a judge, that formalizes an agreement reached between EPA and potentially responsible parties (PRPs) through which PRPs will conduct all or part of a cleanup action at a Superfund site, cease or correct actions or processes that are polluting the environment, or otherwise comply with EPA-initiated regulatory enforcement actions to resolve the contamination at the Superfund site involved. The consent decree describes the actions PRPs will take and may be subject to a public comment period.

Conventional pollutants: Pollutants typical of municipal sewage, and for which municipal secondary treatment plants are typically designed; defined by Federal Regulation [40 CFR 401.16] as BOD, TSS, fecal coliform bacteria, oil and grease, and pH.

Daily discharge: The discharge of a pollutant measured during any 24-hour period that reasonably represents a calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the daily discharge is calculated as the total mass of the pollutant discharged during the day. For pollutants with limitations expressed in other units of measurement (e.g., concentration) the daily discharge is calculated as the average measurement of the pollutant throughout the day (40 CFR 122.2).

Denitrification: The chemical or biological reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen (N_2) or as an oxide of nitrogen (N_2O).

Direct discharger: A facility that discharges or may discharge treated or untreated wastewaters into waters of the United States.

Dissolved oxygen (DO): Oxygen dissolved in water by diffusion from the atmosphere and through the release into the water as a by-product of photosynthesis in aquatic plants; a water quality parameter.

Drug: Any substance, including medicated feed, that is added to a production facility to maintain or restore animal health and that subsequently might be discharged to waters of the United States.

Effluent limitations guideline (ELGs): Under the Clean Water Act, section 502(11), any restriction, including schedules of compliance, established by a state or the Administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents that are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean (Clean Water Act sections 301(b) and 304(b)).

End-of-pipe treatment practices: Technologies such as settling basins or microscreens that reduce discharge of pollutants after they have formed.

Escapement: The release of aquatic animals from a production facility to waters of the United States.

Eutrophication: A process in which the addition of nutrients (primarily nitrogen and phosphorus) to water bodies stimulates algal growth. This is a natural process, but it can be greatly accelerated by human activities.

Excess feed: Feed that is added to a production system, is not consumed, and is not expected to be consumed by the aquatic animals.

Existing source: For a categorical industrial user, any source of discharge, the construction or operation of which commenced prior to the publication of proposed categorical pretreatment standards under Section 307 of the Clean Water Act.

Facility: All contiguous property and equipment owned, operated, leased, or under the control of the same person or entity.

Feed conversion ratio (FCR): A measure of feeding efficiency that is calculated as the ratio of the weight of feed applied to the weight of the fish produced.

Finfish: A term used to delineate bony fishes from other aquaculture species such as crustaceans and molluscs.

Fingerling: Juvenile fish that are typically 2 to 6 inches long or weigh 2 to 60 pounds per 1,000 fish.

Floating or bottom aquaculture system: A system used for the production of molluscs and shellfish. The cultured species can be grown attached to or lodged in the substrate or suspended from strings or cages.

Flow-through system: A system designed for a continuous water flow to waters of the United States through chambers used to produce aquatic animals. Flow-through systems typically use either raceways or tank systems. Raceways are fed by nearby rivers or springs and are typically long, rectangular chambers at or below grade, constructed of earth, concrete, plastic, or metal. Tank systems are similarly fed and concentrate aquatic animals in circular or rectangular tanks above grade. The term does not include net pens.

Foodfish: Fish for human consumption, typically over 0.75 pound.

Forage crop: Crop planted to provide food for crawfish when the ponds are flooded in the fall; rice is a common forage crop.

Frequency factors: The regional compliance of animal feeding operations with best management practices associated with a nutrient management plan, facility upgrades, or strategies to reduce excess nutrients.

Fry: Young fish that are typically under 2 inches long or weigh less than 2 pounds per 1,000 fish.

Groundwater: Water in a saturated zone or stratum beneath the surface of land or water.

Herbivore: An animal that feeds on plants.

Indirect discharger: A facility that discharges or may discharge wastewaters into a publicly owned treatment works.

Loading density: The average stocking density of the culture species within the production system at maximum production levels.

Long-term average (LTA): For purposes of the effluent guidelines, average pollutant levels achieved over a period of time by a facility, subcategory, or technology option. LTAs were used in developing the effluent limitations guidelines and standards in the proposed regulation.

Maximum monthly discharge limitation: The highest allowable average of "daily discharges" over a calendar month, calculated as the sum of all "daily discharges" measured during the calendar month divided by the number of "daily discharges" measured during the month.

Microbial decomposition: The breakdown of complex molecules in either plant or animal matter by bacteria and fungi.

Minimum level: The level at which an analytical system gives recognizable signals and an acceptable calibration point.

National Pollutant Discharge Elimination System (NPDES) permit: A permit to discharge wastewater into waters of the United States issued under the National Pollutant Discharge Elimination System, authorized by section 402 of the Clean Water Act.

National Pollutant Discharge Elimination System (NPDES) program: The NPDES program authorized by sections 307, 318, 402, and 405 of the Clean Water Act. It applies to facilities that discharge wastewater directly to U.S. surface waters.

Navigable waters: Traditionally, waters sufficiently deep and wide for navigation by all, or specified vessels; such waters in the United States come under federal jurisdiction and are protected by certain provisions of the Clean Water Act.

Net pen system: A stationary, suspended, or floating system of nets or screens in open marine or estuarine waters of the United States. Net pen systems typically are located along a shore or pier or may be anchored and floating offshore. Net pens and cages rely on tides and currents to provide a continual supply of high-quality water to animals in production.

New Source Performance Standards (NSPS): Technology-based standards for facilities that qualify as new sources under 40 CFR 122.2 and 40 CFR 122.29. Standards consider that the new source facility has an opportunity to design operations to more effectively control pollutant discharges.

Nonconventional pollutants: Pollutants that are neither conventional pollutants nor priority pollutants listed at 40 CFR 401.15 and Part 423, Appendix A.

Nonnative aquatic animal species: An individual, group, or population of species found (1) to be outside its historical or native geographic range and (2) to threaten native aquatic biota determined and identified by the appropriate state authority or U.S. Fish and Wildlife Service. This term excludes species raised for stocking by public agencies.

Non-water quality environmental impacts: Deleterious aspects of control and treatment technologies applicable to point source category wastes, including, but not limited to, air pollution, noise, radiation, sludge, and solid waste generation, and energy used.

North American Industry Classification System (NAICS): System developed jointly by the United States, Canada, and Mexico to provide new comparability in statistics about business activity across North America.

Ocean ranching: The process of rearing smolts and releasing them into the wild (the ocean), from which they are later harvested.

Omnivore: An animal that feeds on both animal and vegetable substances.

Outfall: The mouth of the conduit drains and other conduits from which a facility effluent discharges into receiving waters.

Pass through: A discharge which exits the POTW into waters of the United States, or state of Washington, in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the city's NPDES permit including an increase in the magnitude or duration of a violation.

Pathogen: A predatory or parasitic organism present in water or aquatic animals that, when discharged to waters of the United States, threatens disease in aquatic animals or humans.

Pelagic: Of, relating to, or living or occurring in the open sea.

Permitting authority: The agency authorized to administer the National Pollutant Discharge Elimination System permitting program in a state or territory.

Phytoplankton: Microscopic plants that serve as the plant food base for other organisms (zooplankton and larger animals) that are then consumed by fish. Phytoplankton is often referred to as the base of the food chain.

Planktonic: Relating to, being, or characteristic of plankton, a wide variety of plant and animal organisms that float or drift freely in water.

Point source: Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. See Clean Water Act section 502(14).

Pollutant load: The amount of a specific pollutant in a wastewater stream measured in mass units (pounds, kilograms).

Pollutants of concern (POCs): Pollutants commonly found in concentrated aquatic animal production facilities wastewaters. Generally, a chemical is considered a POC if it is detected in untreated process wastewater at five times a baseline value in more than 10 percent of the samples.

Pond system: An impoundment of water used for the production of aquatic animals. Pond systems are the most widely used production system in the aquatic animal production industry.

Pretreatment standards for existing sources (PSES) of indirect discharges: Under section 307(b) of the Clean Water Act, standards applicable (for this rule) to indirect dischargers that commenced construction prior to promulgation of the final rule.

Pretreatment standards for new sources (PSNS): Under section 307(c) of the Clean Water Act, standards applicable to indirect dischargers that commence after promulgation of the final rule.

Protozoa: Unicellular organisms that live individually or in small groups. Many kinds of protozoa are harmful to aquaculture animals. In some aquaculture systems, parasitic protozoa are the most important disease agents.

Publicly owned treatment works (POTW): A treatment works as defined by section 212 of the Clean Water Act, which is owned by a state or municipality (as defined by section 502(4) of the Clean Water Act). This definition includes any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes, and other conveyances, only if they convey wastewater to a POTW. The term also means the municipality, as defined in section 502(4) of the Clean Water Act, that has jurisdiction over the indirect discharges to and the discharges from such a treatment works.

Quiescent zones: Solids-collection zones placed at the end of a raceway tank to collect the settleable solids swept out of the fish-rearing area. They are the primary means for solids removal in flow-through raceways.

Raceways: Culture units in which water flows continuously, making a single pass through the unit before being discharged; these systems are also referred to as flow-through systems.

Resource Conservation and Recovery Act (RCRA) of 1976: (42 U.S.C. sections 6901 et seq.). RCRA regulates the generation, treatment, storage, disposal, or recycling of solid and hazardous wastes.

Recirculating system: A system that filters and reuses water in which aquatic animals are produced prior to discharge. Recirculating systems typically use tanks, biological or mechanical filtration, and mechanical support equipment to maintain high-quality water to produce aquatic animals.

Seine: A net with weights attached to the bottom and floats on the top that can be pulled from each end to enclose fish during harvest.

Settleable solids: Material heavy enough to sink to the bottom of a wastewater treatment tank.

Sludge: Settled sewage solids combined with varying amounts of water and dissolved materials that are removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion.

Smolt: A young salmon ready for life in a saltwater environment.

Sole proprietorship: An unincorporated business owned by one person, who is entirely liable for all business debts. A sole proprietor files either IRS Schedule C (profit or loss from a business) or Schedule F (profit or loss from farming). This Schedule becomes part of the owner's Form 1040 (personal tax form).

Spawning ground: A specific site where fish lay their eggs.

Standard industrial classification (SIC): A numerical categorization system used by the U.S. Department of Commerce to catalogue economic activity. SIC codes refer to the products, or group of products, produced or distributed, or to services rendered by an operating establishment. SIC codes are used to group establishments by the economic activities in which they are engaged. SIC codes often denote a facility's primary, secondary, tertiary, etc. economic activities.

Stockers: Fish used for stocking public or private fishing areas that are typically more than 6 inches long or weigh 60 to 750 pounds per 1,000 fish.

Total dissolved solids (TDS): All material that passes the standard glass river filter; now called total filtrable residue. Term is used to reflect salinity.

Total Kjeldahl nitrogen (TKN): Water and wastewater analyte that indicates the sum of organic nitrogen and ammonia nitrogen in the matrix analyzed.

Total nitrogen: Sum of nitrate/nitrite and total Kjeldahl nitrogen.

Total organic carbon (TOC): The fraction of carbon covalently bound to organic molecules within a sample.

Total suspended solids (TSS): The weight of particles that are suspended in water. Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organics and metals tend to bind to particles. Differentiated from total dissolved solids by a standardized filtration process whereby the dissolved portion passes through the filter.

Total volatile solids (TVS): Those solids in water or other liquids that are lost on ignition of the dry solids at 550 °C.

Turbidity: A measure of light penetration in water. Produced by dissolved and suspended substances. The more dense these substances, the higher the turbidity.

Volatile compound: Any substance that evaporates readily.

Wastewater treatment: The processing of wastewater by physical, chemical, biological, or other means to remove specific pollutants from the wastewater stream, or to alter the physical or chemical state of specific pollutants in the wastewater stream. Treatment is performed for discharge of treated wastewater, recycle of treated wastewater to the same process that generated the wastewater, or reuse of the treated wastewater in another process.

Zooplankton: The animal portion of plankton, which makes up the primary and secondary food chains in most bodies of water and is generally passively floating, or weakly swimming, minute animal or plant life. Zooplankton generally feed on phytoplankton. In turn, zooplankton provide an important food source for larval fish and shrimp in aquaculture ponds.

APPENDIX A
SURVEY DESIGN AND CALCULATION OF NATIONAL ESTIMATES

APPENDIX A: SURVEY DESIGN AND CALCULATION OF NATIONAL ESTIMATES

EPA has collected information from aquatic animal production by using a two-phase sample design with a questionnaire in each phase. A two-phase[1] sample design is a standard survey statistic technique (see, for example, Cochran (1977) or Kish (1965)). In the first phase of this design, information is collected from every unit (e.g., facility) in the sample. In the second phase, detailed information is collected from each unit in a second, smaller, sample. Typically, the first phase sample is used to classify the population for the second phase sample and this second sample is selected from the units in the first sample. Statistical inference can be made using the information from the second phase alone or in some combination of the first and second phases.

In the first phase conducted in August 2001, EPA sent a short screener questionnaire, entitled “Screener Questionnaire for the Aquatic Animal Production Industry” (“screener questionnaire,” USEPA, 2001) to a list of 5939 possible aquatic animal production (AAP) facilities. This sample frame (list) is discussed in Section A.1 below. The screener questionnaire consisted of eleven questions to solicit general facility information, including confirmation that the facility was engaged in aquatic animal production, species and size category produced, type of production system, wastewater disposal method, and the total production at the facility in the year 2000. Section A.2 describes the census conducted in this first phase and the data analysis of the responses.

In the second phase conducted in June 2002, EPA sent the detailed questionnaire, “Detailed Questionnaire for the Aquatic Animal Production Industry,” (“detailed questionnaire,” USEPA, 2002) to 263 concentrated aquatic animal production (CAAP) facilities selected from the screener questionnaire respondents. EPA designed this second questionnaire to collect detailed site-specific technical and financial information. The detailed questionnaire is divided into three parts. The first two parts collect general facility, technical, and cost data. The third part of the detailed questionnaire elicits site-specific financial and economic data. EPA sent each facility only the portions of each part that were relevant to the operations reported in the screener questionnaire. Section A.3 describes the sample selection criteria and estimation procedures from the responses from this second phase. Because EPA has not yet evaluated the results from this questionnaire, Section A.3 provides only a general overview of EPA’s approach to calculating national estimates for the final rule.

A.1 SAMPLE FRAME

In 1998, the US Department of Agriculture (USDA) identified 4,028 aquaculture facilities in its Census of Aquaculture (“USDA Census”). Because their database was

[1] Some textbooks and journal articles refer to two-phase sampling as ‘double sampling.’

confidential and thus not available, EPA constructed a sampling frame from alternative sources consisting of data received from Dun & Bradstreet, augmented with supplemental sources of facilities. Attachment A-1 to this appendix summarizes the differences between the sample frames and other aspects of the two questionnaires.

EPA developed its initial list of facilities from the February 2001 version of the Dun & Bradstreet (D&B) database. D&B provided a list of 2,025 facilities whose primary, secondary, or tertiary SIC codes related to AAP. The SIC codes included 0273 (animal aquaculture), 0279 (animal specialties), and 0921 (fish hatcheries and preserves). EPA found that the D&B database only contained half as many facilities as the USDA Census, 2,025 compared to 4,028. Although the size of the industry may have changed between 1998 (USDA Census) and 2001 (D&B), it was more likely that D&B did not include some facilities identified by the USDA. EPA then examined the total revenue of facilities in the D&B database, and found that it exceeded that of the Census by about ten percent. Because both estimates of total revenue were about $1.0 billion, EPA concluded that the facilities not included in the D&B database probably were quite small.

In order to identify AAP facilities not identified by the D&B database, a number of secondary sources were identified and utilized. About 4,000 facilities were identified from supplemental sources. These included:

- An initial list of 2,241 facilities supplied by 24 state agencies such as Departments of Agriculture or Environmental Protection. These data varied considerably in quality and utility, including some lists that were incomplete and/or out of date.

- US Fish and Wildlife Service

- The Internet, associations, and trade journals.

- EPA used its own list of 288 farms from which a subset of 121 new listings in 28 states was identified. EPA developed this list of 288 farms from its Permit Compliance System (PCS), Discharge Monitoring Reports (DMR), and other permit information. In addition, some additional facilities were added from a list of 30 facilities on EPA's site visit list.

- The frame was augmented with a list of public aquariums in the United States. These were identified largely through the Internet as well as data supplied by the American Zoo and Aquarium Association.

Identification and deletion of duplicate facilities (i.e., those appearing more than once on the list, perhaps with slightly different addresses or company names) was conducted both prior to and after mailing the questionnaires. In order to ensure that no active AAP facility would be inadvertently removed, only obvious duplicates were deleted prior to the mailing.

A.2 SCREENER QUESTIONNAIRE (PHASE 1)

This section describes the screener questionnaire responses that were collected in Phase 1 of EPA's survey of the AAP industry. Section A.2.1 describes the sample design, which was a census of the industry, and the number of responses. Section A.2.2 describes the data analysis of the responses including the use of conversion factors; development of sample weights that adjust for non-response; and the estimation of national totals, national means, and their standard errors.

A.2.1 Sample Design: Census

In Phase 1, the screener questionnaires were mailed to all 5934[2] addresses on the frame. Because they were mailed to all facilities on the sample frame, the sample design for this phase is considered to be a 'census.' After the mailing, 53 unsolicited questionnaires were received that were not on the original mailing list. Many of these were from facilities that operated more facilities than the number of questionnaires that they received. In its data analyses and selection of the sample for the second phase, EPA considers these 53 facilities as if they were part of the original sample frame. Thus, the 'final' frame contained 5987 potential AAP facilities.

As of 8/8/02, EPA had received 4199 completed, 58 incomplete, and 75 blank questionnaires. EPA also had identified an additional 161 duplicate questionnaires (i.e., more than one questionnaire was sent to the same facility). For questionnaires returned by the delivery service, EPA attempted various data retrieval and searches to obtain a better mailing address. For 435 addresses, EPA was unsuccessful in finding better addresses, and thus, EPA assumed that these facilities did not exist (e.g., out of business). In addition, although they received a letter reminding them to return the questionnaire, 1064 facilities did not return their questionnaires and are considered to be 'non-respondents' in the statistical analysis presented in this appendix. (Five of the 1064 facilities returned a blank questionnaire and also are considered to be non-respondents.)

Response rates can be calculated in various ways. One widely accepted method is to use the ratio of the number of returned questionnaires to the number of valid addresses. EPA was able to determine the number of valid addresses because the delivery service required recipients to sign a manifest. For the screener questionnaire, the number of valid addresses was 5552, that is, the remainder of the 5987 potential AAP facilities after subtracting the 435 addresses without a viable address. The response rate of 75.6 percent is the ratio of the 4199 completed questionnaires to the 5552 valid addresses.

From the completed questionnaires, EPA identified 2329 facilities in the AAP industry. These facilities answered 'Yes' to question 1 which asked 'Do you produce (grow) aquatic animals (fish, shellfish, other aquatic animals) at this facility?'

---

[2] Elsewhere in this document and other record materials, EPA may have identified the total number of questionnaires as 5939; however, five were replacements of questionnaires with incomplete mailing labels. In some summaries, EPA includes the replacements as five new questionnaires.

A.2.2 Data Analysis

Elsewhere in this document, the preamble to the proposed rule, and the proposal record, EPA has presented summary statistics of the AAP industry without weighting the results to adjust for the non-response rate.[3] Weighting the data allows inferences to be made about all eligible facilities, including those that did not respond to the questionnaire. Another advantage is that weighted estimates have smaller variances than unweighted estimates (i.e., counts of the responses). Because of time constraints for the proposal, EPA was unable to incorporate these weighted results into its other analyses, such as economic achievability. However, EPA is likely to incorporate these weighted results into its analyses for the final rule, and this section presents its methodology for calculating the weighted results presented in Attachment A-3.

This section consists of three subsections. Section A.2.2.1 describes various conversion factors and their application in determining the biomass, predominant species, predominant production method, and total revenue at each facility. Section A.2.2.2 describes the sample weights that adjust for non-response. Section A.2.2.3 describes the application of these sample weights in developing national estimates (e.g., number of facilities with trout as their predominant species) and the standard errors of these estimates.

A.2.2.1 Use of Conversion Factors

To simplify its data analyses, EPA determined the biomass, predominant species and predominant production method for each facility, using various conversion factors in Attachment A-2. This section describes the use of the conversion factors and these determinations.

Biomass

For each size category, the screener questionnaire collected production in any of six units (pounds (live weight), number or count, live dry bushels, dozens, dollars sold, or other). To estimate the production at a facility, EPA converted all units into pounds (lbs) using conversion factors from sources such as the USDA Census of Aquaculture, industry experts, internet sites about fish, and calls to aquaculture farms (see DCN 50070 in Section 10.3 of the proposal record). As shown in Tables A2.1 and A2.2 in Attachment A-2, the conversion factors depended on the species, the size category, and the reported units. When specific conversion factors were not available (for a minority of facilities), EPA used approximate conversion factors based on 1) the weight of food-size animals for

---

[3] As explained in the preamble to the proposed rule, in order to estimate the national pre-tax annualized compliance costs attributed to the proposed rule, EPA multiplied the commercial facilities by a factor of 2.5. This factor was estimated by calculating the ratio of the number of potentially regulated facilities identified in the USDA Census to the number of potentially regulated facilities identified in the responses to the screener questionnaire. A more detailed explanation of this analysis can be found in the EA [CAAP Economic Analysis] and rulemaking record (DCN 61793). The memorandum 'Alternative weighting plan' (Westat, 2002a) describes alternative methods of using the USDA Census results in weighting the EPA's results from the screener questionnaire.

the species, 2) an approximate weight ratio of food size to other size animals, and 3) approximate conversion factors from the reported unit into pounds. As an example of using the appropriate conversion factor in Table A2.1, if a facility produced 1,000 catfish of foodsize, the biomass of the catfish was calculated as

1,000 catfish x 1.5 lbs/catfish=1,500 lbs.

As another example, if a facility produced 1,000 whitefish of stocker size, the biomass was calculated using the conversion factor for whitefish of foodsize from Table A2.1 and the stocker size conversion factor from Table A2.2, as follows:

1,000 $\text{whitefish}_{\text{stocker}}$ x 2.5 lbs/$\text{whitefish}_{\text{foodsize}}$ x 0.1418 $\text{whitefish}_{\text{foodsize}}$ / $\text{whitefish}_{\text{stocker}}$ = 354.5 lbs.

The *total biomass*, or total production, for a facility is the total weight in pounds across all size and species categories.

Predominant Species

To determine the predominant species, EPA calculated the biomass for each species reported by a facility. The species biomass was the total weight in pounds across all size categories for that species. EPA then selected the species with the largest biomass as the predominant species.

Predominant Production Method

In response to question 6 on the screener questionnaire, facilities could specify any of six different production methods (ponds, flow through systems, recirculating systems, net pens or cages, floating aquaculture, and other). However, the screener questionnaire requested species and production information separately from the production method. Thus, for facilities with multiple species, it was not possible to determine which production method was used for a particular species. Also, some facilities reported more than one production method. To assign a single production method to a facility's predominant species, EPA ordered the production methods from most common to least common among facilities with the same predominant species. Table A2.3 in Attachment A-2 presents this ordering of production methods. (As noted in the table, EPA used a slightly different ordering sequence for the data analyses presented in Attachment A-3, than it did for the sample selection for the detailed questionnaire.) As an example, *assume* a facility has catfish as the predominant species and uses both recirculating systems and flow through systems. From Table A2.3, the most common production method for facilities with catfish as the predominant species is ponds; however, ponds are not used at this facility. The second most common production method is flow through systems. Because this facility uses flow through systems, EPA would assume that these flow through systems are the predominant production method for catfish production at this facility.

Total Revenue

In response to question 5 of the screener questionnaire, facilities could report production in any of six units: pounds (live weight), number or count; live dry bushels; dozens; dollars sold; and other. Most facilities reported their total production in pounds, counts, or dollars. To convert the production units into dollars, EPA used the conversion factors in Table A2.4, in Attachment A-2, to estimate the number of facilities that would be subject to the proposed rule in three revenue classes: $20,000-$100,000; $100,000-$499,999, and >$500,000.

As explained in the preamble to the proposed rule, in evaluating the screener questionnaire responses to question 5 (production), EPA used six production size categories that correspond with the revenue classifications used in the 1998 Census of Aquaculture (i.e., $1,000-$24,999; $25,000 - $49,999; $50,000 - $99,999; $100,000 - $499,999; $500,000 - $1,000,000; and >$1,000,000). These classifications were used to develop model facilities representing these size ranges for each species evaluated. Because of the small numbers of facilities in some for the species and production method categories, EPA has not presented these results to protect confidential business information.

A.2.2.2 Sample Weights

This section describes the methodology used to calculate the base weights, non-response adjustments, and the final weights for the screener questionnaire. The sample weights accounted for different response rates and ineligible facilities. In conjunction with the conversion and predominant determinations described in the last section, the sample weights were used to calculate the national estimates presented in Attachment A-3.

The *base weight* is equal to 1.0 for all facilities because the screener questionnaire was sent to the entire sample frame (i.e., a census).

$$base\ weight = 1.0 \tag{A-1}$$

The number of returned questionnaires includes duplicate questionnaires, whether they were completed or not, but does not include questionnaires that were not deliverable. The non-response adjustment in effect spreads the weight associated with the non-responses (questionnaires not returned) across the responses. The non-response adjustment assumes that the fraction of duplicate addresses among those who responded is the same as the fraction among those who did not respond. Because different species tend to be located in different parts of the country, EPA decided to use the facility location as a basis for calculating the non-response rate. For states with 50 or more respondents, EPA defined the location of the facility as its state. For states with less than 50 respondents, EPA grouped the facilities into one strata. (See Westat, 2002b, for a logistic regression that assessed which factors were significant predictors of non-response.) Within each stratum g, the non-response weight adjustment is the ratio of the number of facilities with valid addresses to the number that responded.

$$w_g = (non-response\ adjustment)_g = \frac{Number\ of\ valid\ addresses\ in\ stratum\ g}{Number\ of\ returned\ questionnaires\ in\ stratum\ g} \quad \text{(A-2)}$$

The final screener weight w_i for facility i in non-response stratum g can be written as:

$$w_{gi} = (base\,weight) \times (non-response\,adjustment)_g = 1.0 \times w_g = w_g \quad \text{(A-3)}$$

Although the weight is applicable to all responding facilities, EPA is interested in only those facilities in AAP. For each non-response strata g, Table A.1 shows the number of valid addresses (excluding any duplicate addresses), the number of returned questionnaires, the screener weight, and the number of responding AAP facilities. The weights for the screener respondents ranged from 1.14 to 1.55.

As an example of the application of the screener weights, consider strata 1 which had 124 valid addresses and 93 returned questionnaires. The sample weight is:

$$w_{1i} = 1.0 \times \left(\frac{124}{93}\right) = 1.33$$

As shown in the last column, 56 of the 93 returned questionnaires are from AAP facilities. Then, using the sample weight, the estimated number of AAP facilities is 1.33 x 56 = 75 (rounded to an integer).

Using a non-response adjustment assumes that the fraction of facilities doing AAP is the same among the respondent and non-respondents. In its data analyses of the screener questionnaire responses, EPA has assumed that non-respondents have the same characteristics, proportionally, as the respondents. This is a common technique used in survey estimation, although it is likely to incorporate some bias into the estimates. There is considerable research into the area of non-response estimation (see, for example, Groves and Couper (1998)).

Table A.1. Screener Weights and Number of Facilities by Non-Response (Location) Strata

Non-Response (Location) Stratum	*Number of Valid Addresses*	*Number of Returned Questionnaires*	*Screener Weight* w_g	*Number of Responding AAP Facilities in the Stratum*
1 (AK)	124	93	1.333	56
2 (AL)	162	111	1.459	74
3 (AR)	450	323	1.393	164
4 (CA)	316	249	1.269	144
5 (CO)	65	52	1.250	30
6 (FL)	524	410	1.278	125
7 (GA)	155	118	1.314	69

Non-Response (Location) Stratum	Number of Valid Addresses	Number of Returned Questionnaires	Screener Weight w_g	Number of Responding AAP Facilities in the Stratum
8 (HI)	163	105	1.552	50
9 (IA)	67	57	1.175	31
10 (ID)	109	92	1.185	59
11 (IN)	68	55	1.236	29
12 (LA)	246	182	1.352	119
13 (MA)	323	218	1.482	114
14 (ME)	100	73	1.370	50
15 (MI)	107	85	1.259	51
16 (MO)	74	65	1.138	44
17 (MS)	220	163	1.350	121
18 (NC)	261	194	1.345	123
19 (NE)	117	86	1.360	35
20 (NY)	116	93	1.247	53
21 (OH)	70	58	1.207	35
22 (OK)	68	55	1.236	31
23 (OR)	99	74	1.338	55
24 (PA)	75	64	1.172	44
25 (TX)	308	254	1.213	122
26 (VA)	114	90	1.267	40
27 (WA)	217	162	1.340	102
28 (WI)	226	171	1.322	98
29 (Other States)	615	462	1.331	261
Total	5559	4214		2329

A.2.2.3 National Estimates and Standard Errors

This section presents the general methodology and equations for estimating national totals, national means, and their standard errors, from the responses to the screener questionnaire.

Estimates of national totals were obtained for each characteristic and domain of interest by multiplying the reported value by the screener weight and by summing all weighted values for the facilities that belong to the domain of interest *k*:

$$\hat{y}_k = \sum_g \sum_i w_{gi} \, y_{kgi} \, I_{gi \in k} \qquad \text{(A-4)}$$

Where $I_{gi \in k}$ is one if facility *i* in stratum *g* is in domain *k* and zero otherwise. For example, if the domain of interest was 'Facilities in Western USDA Region,' y_{gi} was the trout production at each facility *i* in stratum *g*, and w_{gi} was the screener weight for that facility, then $\hat{y}_k$ was the estimate of trout production for facilities in the Western USDA region.

Similarly, ratio estimates (for example, means and percentages) in a given domain *k* were obtained as a ratio of estimates of two total values. For example, the average trout production in the Western USDA region was the ratio of the estimate of trout production, $\hat{y}_k$ in that region, and the estimate of the number of facilities in that region producing trout, n_k:

$$\bar{y}_k = \frac{\hat{y}_k}{n_k} = \frac{\sum_g \sum_i w_{gi} y_{kgi} I_{gi \in k}}{\sum_g \sum_i w_{gi} I_{gi \in k}}. \qquad \text{(A-5)}$$

After calculating the national estimates, EPA calculated standard errors (s.e.) of its estimates using a jackknife replication method. (Wolter, 1985) Under the jackknife replication method, a series of samples (called jackknife replicates) are selected from all responses (*n*). EPA created 100 replicates to obtain 99 degrees of freedom which EPA considered to be adequate for the statistical estimates while resulting in reasonably sized data files for the replicates. Each facility response was randomly assigned a number between 1 and 100. The first replicate used the responses from all facilities except those assigned to group 1. The other replicates were derived in a similar way by excluding the values for a different group each time. The replicate weights were used to adjust the replicate sample size for the missing group. That is, if there were 100 responses in a non-response (location) stratum and 10 responses were randomly assigned to group *r*, then the replicate weight adjustment for that stratum, w_r, was the ratio, 1.11, of the 100 responses (n=100) and the 90 responses ($n_{(r)}$=90) in the replicate sample. In this way, a series of replicate weights were generated for each facility response, which together with the screener weight were used to calculate national estimates and averages:

$$\hat{y}_{(r)} = \sum_g \sum_{i \notin r} w_{gi} w_{g(r)} y_{kgi} I_{gi \in k} \qquad \text{(A-6)}$$

$$\bar{y}_{(r)} = \frac{\hat{y}_{(r)}}{n_{(r)}} = \frac{\sum_g \sum_{i \notin r} w_{gi} w_{g(r)} y_{kgi} I_{gi \in k}}{\sum_g \sum_{i \notin r} w_{gi} w_{g(r)} I_{gi \in k}}. \qquad \text{(A-7)}$$

In order to illustrate how the sampling errors are calculated, let $\bar{y}$ be the weighted national average estimate of a characteristic *y* (e.g., average trout production at facilities that produce trout). If $\bar{y}_{(r)}$ is the corresponding estimate calculated using the facility responses for all groups except group *r*, then the estimated variance of *y* is given by the following formula:

$$\operatorname{var}(\bar{y}) = \frac{99}{100}\sum_{r=1}^{100}\left(\bar{y}_{(r)} - \bar{y}\right)^2 \qquad \text{(A-8)}$$

where the summation extends over all 100 jackknife replicates that were formed from the screener responses. The standard error is then the square root of the variance:

$$s.e. = \sqrt{\operatorname{var}(\bar{y})} \qquad \text{(A-9)}$$

In Attachment A.3, the tables provide various estimates and their standard errors. These standard errors can be used to compute 95 percent confidence intervals around the estimate. These intervals are given by:

$$confidence\ interval = \bar{y} \pm (1.96 \times s.e.) \qquad \text{(A-10)}$$

A.3 DETAILED QUESTIONNAIRE (PHASE 2)

This section describes the detailed questionnaire that was distributed in Phase 2 of EPA's survey of the AAP industry. Section A.3.1 describes the sample design and sample selection for the detailed questionnaire based upon the responses to the screener questionnaire in Phase 1. Section A.3.2 describes the methods that EPA is likely to use in developing national estimates from the responses to the detailed questionnaire.

A.3.1 Sample Design: Stratified Random Sample

After reviewing the results from the screener questionnaire, EPA decided that the information from the detailed questionnaire was needed for only a subset of the AAP facilities. Because the proposed rule is applicable only to concentrated aquatic animal production (CAAP) facilities, EPA was particularly interested in facilities, classified as either Commercial, Government, Research, or Tribal, and subject to the current NPDES regulations. (40 CFR 122.24 and Appendix C to Part 122.) According the the NPDES regulations, CAAP facilities can be in either of two categories: cold water or warm water. The cold water species category includes ponds, raceways, or other similar structures which discharge at least 30 days per year but does not include: facilities which produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) per year of trout or salmon; and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) during the calendar month of maximum feeding. The warm water category includes ponds, raceways, or other similar structures which discharge at least 30 days per year but does not include: closed ponds which discharge only during periods of excess runoff; or facilities which produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) per year of any species except trout and salmon. Although EPA excluded ponds from the proposed rule, EPA determined that it needed additional information from facilities with ponds and large production volumes to evaluate whether EPA had appropriately excluded such facilities from the proposed rule.

EPA also considered aquariums to assess concerns from interested parties, particularly with respect to drug and chemical use. EPA selected these based upon the facility name, responses to questions 4 and 5, and additional information from an industry trade association.

After considering these factors, EPA determined that it should sample facilities meeting one of the following six criteria:

1. Aquariums.

2. Production includes alligators and total biomass exceeds 100,000 pounds.

3. Production includes trout or salmon and total biomass exceeds 20,000 pounds.

4. Predominant production method is ponds; predominant species is catfish; and total biomass exceeds 2,200,000 pounds.

5. Predominant production method is ponds; predominant species is shrimp, tilapia, other finfish, or hybrid striped bass; and total biomass exceeds 360,000 pounds.

6. Predominant production method is any *except* ponds; and total biomass exceeds 100,000 pounds.

By applying these criteria, EPA identified 539 facilities with these characteristics from the screener questionnaire responses. In developing the sample selection criteria, EPA determined each facility's predominant species and predominant production method as explained in Section A.2.2.1, except that it excluded molluscan shellfish from its determination of the predominant species.[4] EPA then classified the 539 facilities into 44 strata which were defined by facility type (commercial, government, research, or tribal),[5] the predominant species, and predominant production.

In calculating the sample sizes, EPA used a common method for estimating sample sizes that is based upon the binomial distribution (see, for example, Cochran (1977)). The binomial distribution applies to situations where there are only two possible outcomes. For example, there are only two outcomes (yes or no) to a dichotomous question such as 'Does any of this water go to a publicly owned treatment works.' Because the assumption results in the largest possible variance for the binomial distribution and the largest possible sample size, this method assumes that the probability of one outcome would be 0.5 (i.e., 50 percent would select 'Yes' and 50 percent select 'No.') This probability is

[4] Before selecting the sample for the detailed questionnaire, EPA evaluated the impact of its 'approximate' conversion factors in the total biomass calculations described in Section A.2.2.1. Because it had identified facilities with production close to the cutoff for inclusion into the selected strata and expended additional effort to obtain more precise conversion factors, the use of approximate conversion factors had relatively little effect.

[5] Facility type was determined by the facility's response to question 4 of the screener questionnaire. If the facility type was missing (7 cases) or indicated as being 'Other,' EPA excluded these facilities from consideration for the detailed questionnaire.

written as 'p=0.5.' EPA used this probability (p=0.5) and its precision targets to derive the sample sizes. EPA's criteria for its sample can be summarized as follows:

1. For estimates for each stratum: a 95% confidence interval for p=0.5 is (0.2, 0.8); *and*

2. For overall estimates (i.e., of the entire population meeting the criteria above): a 95% confidence interval for p=0.5 is (0.45, 0.55); *and*

3. No one facility unduly influences the overall estimate.

To achieve the desired precision, EPA determined that information should be collected from 263 of the 539 facilities in the 44 strata. For 34 strata with five or fewer facilities, EPA determined that a census was appropriate because of the relatively small sample sizes, and thus, selected the 163 facilities in those strata. (Of these 34 strata, 20 strata contained only one facility.) For the other 10 strata, EPA selected 200 of the 376 facilities. Table A.2 lists the variables defining each stratum, the number of facilities in the stratum (N_h), the number of facilities in the sample (n_h), and the sampling weight. The number of facilities are based on the responses to the screener questionnaire, without adjusting for non-response. As shown in Table A.2, the sampling weights are fairly consistent, ranging from 1.0 to 2.6. (Although aquariums and alligators are not listed in Table A.2, facilities selected for the sample included facilities that were aquariums and alligator farms.)

In selecting the sample for each of the 10 strata, EPA selected the first n_h facilities in alphabetical order. Assuming that the information collected in the detailed questionnaire is not correlated with the alphabetical ordering of the facilities, the sample can be treated as a random statistical sample. By examining the production levels calculated from the screener questionnaire responses in each stratum, the sample appears to be representative of the population in each of the 10 strata (Westat, 2002c). After selecting the sample, EPA identified 8 of the 539 facilities as being duplicates of other facilities; however, they either were not selected for the sample or were only selected once. EPA also identified another facility that should have been excluded from consideration for the detailed questionnaire, because it did not meet the selection criteria. Although the facility was one of the 263 selected to receive the detailed questionnaire, it has been removed from the sample. EPA has concluded that the 262 remaining facilities in the sample will provide acceptable precision estimates for the 530 facilities.

Table A.2 Sampling Strata for Detailed Questionnaire

Facility Type	*Predominant Species*	*Predominant Production Method*	*Number of Facilities (based on Screener Responses)* N_h	*Number of Sampled Facilities* n_h	*Sampling Weight* N_h/n_h
Commercial	Catfish	Flow through	<5	all	1.0
		Ponds	50	20	2.5
	Other	Flow through	<5	all	1.0
		Other	<5	all	1.0
		Ponds	<5	all	1.0

Facility Type	***Predominant Species***	***Predominant Production Method***	***Number of Facilities (based on Screener Responses)*** N_h	***Number of Sampled Facilities*** n_h	***Sampling Weight*** N_h/n_h
		Recirculating	<5	all	1.0
	Trout	Flow through	135	52	2.596
		Net pens	<5	all	1.0
	Salmon	Flow through	16	8	2.0
		Net pens	10	7	1.429
		Recirculating	<5	all	1.0
	Striped Bass	Flow through	<5	all	1.0
		Ponds	<5	all	1.0
		Recirculating	<5	all	1.0
	Tilapia	Flow through	<5	all	1.0
		Recirculating	12	7	1.714
	Other Finfish	Flow through	<5	all	1.0
		Net pens	<5	all	1.0
		Ponds	8	6	1.333
		Recirculating	<5	all	1.0
	Baitfish	Recirculating	<5	all	1.0
	Ornamentals	Flow through	<5	all	1.0
		Recirculating	<5	all	1.0
	Shrimp	Flow through	<5	all	1.0
		Ponds	<5	all	1.0
		Recirculating	<5	all	1.0
Government	Catfish	Flow through	<5	all	1.0
		Ponds	<5	all	1.0
	Trout	Flow through	157	61	2.574
		Other	<5	all	1.0
		Ponds	<5	all	1.0
	Salmon	Flow through	64	25	2.560
		Net pens	<5	all	1.0
		Recirculating	<5	all	1.0
	Striped Bass	Ponds	<5	all	1.0
	Other Finfish	Flow through	<5	all	1.0
		Ponds	12	7	1.714
Research	Catfish	Ponds	<5	all	1.0
	Other	Recirculating	<5	all	1.0
	Trout	Flow through	<5	all	1.0
	Other Finfish	Recirculating	<5	all	1.0
Tribal	Trout	Flow through	<5	all	1.0
	Salmon	Flow through	10	7	1.429
	Other Finfish	Ponds	<5	all	1.0
Totals			537	263	

A.3.2 Data Analysis

EPA will use the information collected by the detailed questionnaires to re-estimate the costs and benefits associated with the proposed regulatory options. These results will be published in a Notice of Data Availability (NODA) prior to final action on the proposed rule. This section provides a preliminary overview of EPA's plans for statistically analyzing these data to estimate national totals, national means, and their standard errors.

Weighting the data allows inferences to be made about all eligible facilities, not just those included in the sample, but also those not included in the sample or those that did not respond to the either the screener or detailed questionnaire. The base weight for a facility responding to the detailed questionnaire is calculated by multiplying the screener weight which adjusted for non-response (see Section A.2.2.2) by the weight from the sample selection for the detailed questionnaire (See Table A.2). The detailed questionnaire base weight for a facility *i* in sampling strata *h* and non-response (location) strata *g* can be written as follows:

$$W_{gi} = w_{gi} \frac{N_h}{n_h} \quad \text{(A-11)}$$

where N_h is the number of facilities in the sample that belong to sampling stratum *h* (N_h and n_h are shown in Table A.2), n_h is the number of facilities selected in the stratum *h* and w_{gi} is the non-response adjusted screener weight from Table A.1. If necessary, EPA will adjust this base weight for any non-response to the detailed questionnaire. In addition, instead of using the values of N_h from Table A.2, EPA will consider using estimates of N_h based upon adjustments for non-response to the screener questionnaire. These estimates would be the same as or greater than the number of facilities in Table A.2.

To obtain national estimates based upon the detailed questionnaire responses, EPA plans to use these sample weights and the methodology described in Section A.2.2.3.

REFERENCES

Brick, J.M., D. Morganstein, R. Valliant. (2000). "Analysis of Complex Sample Data Using Replication." Westat (www.westat.com).

Cochran, W.G. (1977). *Sampling Techniques*. New York: Wiley.

Groves, R.M. and M.P. Couper. (1998). *Nonresponse in Household Interview Surveys.* New York: Wiley.

Kish, L. (1965). *Survey Sampling*. New York: Wiley.

USDA (2000). 1998 USDA Census of Aquaculture. Located at DCN 60605 and http://www.nass.usda.gov/census/census97/aquaculture/aquaculture.htm.

USEPA (2001). “Screener Questionnaire for the Aquatic Animal Production Industry.” DCN 10001 in the proposal record. Also at http://www.epa.gov/waterscience/guide/aquaculture/screenersurvey.pdf.

USEPA (2002). “Detailed Questionnaire for the Aquatic Animal Production Industry.” DCN 10002 in the proposal record.

Westat (2002a). “Alternative weighting plan.” DCN 50050 in Section 10.3.

Westat (2002b). “Logistic Regression Results.” DCN 50058 in Section 10.3.

Westat (2002c). "Analysis of Variance Results" DCN 50057 in Section 10.3.

Wolter, K. (1985). *Introduction to Variance Estimation.* New York: Springer-Verlag.

Attachment A-1. Comparison of USDA Census of Aquaculture and EPA Screener Questionnaire

	USDA Census of Aquaculture	*EPA Screener Questionnaire*	*Difference*
Primary Objective	Economic description of the industry	Data for regulatory analysis	
Year	1998	2000	Two years
Target Population	All “aquaculture farms” from which aquaculture products were sold, or produced for restoration or conservation purposes during the census year (1998).	All "facilities" in the Aquatic Animal Production Industry which answer "Yes" to the question "Do you produce (grow) aquatic animals (fish, shellfish, or other aquatic animals) at this facility?"	EPA did not require that any products be sold for the farm to be included in its population. The USDA Census generally excluded farms that did not sell its products (e.g., state hatcheries). The USDA Census included "other aquaculture products" including algae. The EPA Screener excluded algae and non-animal products. While the USDA includes such farms, only 20 farms report algae and sea vegetables production (Table 19 in USDA (appears to be only about 20 farms in the USDA count.
Frame Source	Answered positively a 1997 Census of Agriculture question on whether there were "fish and other aquaculture products" in 1997. This list was supplemented by other USDA information and lists of State and Federal fish hatcheries.	A mailing list of 5988 facilities was constructed from Dun & Bradstreet, state lists, tribal information, aquaculture journals, various associations, the internet, and aquaculture facilities identified by respondents. The D&B SIC codes included: 0273 (animal aquaculture), 0279 (animal specialties), and 0921 (fish hatcheries and preserves).	Although constructed differently, it is difficult to say how the resulting lists of farms/facilities might differ. Both frames may miss some aquaculture farms or facilities. Total revenue of facilities in the D&B database exceeded that of the Census by about 10%. Both estimates of total revenue were about $1.0 billion. It was concluded that the facilities missed by D&B probably were quite small.
Survey Design	Census	Census	None.
Frame Size	Not available, assumed to be 4028 or more addresses based upon the reported number of farms.	5988 addresses	Differences are due to how the frames were constructed, differences in the target population, or changes in the industry over time.

	USDA Census of Aquaculture	*EPA Screener Questionnaire*	*Difference*
Instrument	Mailed questionnaire augmented with telephone and personal interviews. Telephone calls and personal interviews were used to collect data from non-respondents.	Mailed questionnaire augmented with follow-up phone calls to clarify data. Reminder letters were sent to non-respondents. A limited effort was made to correct invalid addresses.	USDA had little non-response due to intensive follow-up of non-respondents. Screener results were weighted to adjust for non-response to calculate national estimates.
Number of Respondents doing Aquaculture	Apparently 4028, assuming no non-response due to non-response follow-up. Responses to some questions were imputed.	2329	Differences are primarily due to screener non-response as well as frame under-coverage for either questionnaire, changes in the industry over time, and inclusion of non-animal production in the USDA Census.
Estimated Number of Aquaculture facilities nationally	4028 aquaculture farms	3075 AAP facilities	Differences may be due to frame under-coverage for either questionnaire, changes in the industry over time, and inclusion of non-animal production in the USDA Census.
Scope	Collected detailed information relating to on-farm aquaculture practices, size of operation based on water area, production, sales, method of production, sources of water, point of first sale outlets, cooperative agreements and contracts, and aquaculture distributed for restoration or conservation purposes.	Collected information on the type of facility (commercial, Government, Tribal, etc.), quantities of animals produced in 2000 by species and size category, production methods used, whether water from the facility left the property and whether to a POTW and/or with an NPDES permit, and a description of pollution control practices.	Comparable values include production methods, species produced and some production information.
Production Totals for Selected Species	National estimate: Catfish: 593 million pounds Trout: 63 million pounds	Weighted national estimate: Catfish: 637 million pounds Trout: 121 million pounds	For catfish and trout, total screener production is somewhat larger than from the USDA Census. Screener estimates are based on unit conversion assumptions. Comparisons for other species would require additional assumptions. Differences may be due to changes over time and under coverage in the two frames.

ATTACHMENT A-2. CONVERSION FACTORS FOR SCREENER QUESTIONNAIRE RESPONSES

Table A2.1. Biomass Calculations for Predominant Species: Pounds-to-Count Conversion Factors

Species Code[1]	*SPECIES*	*SIZE (Size Category from Question 5 in the Screener)* [2]					
		Foodsize (1)	*Stockers (2)*	*Fingerlings (3)*	*Seed Stock (6)*	*Brood-stock (7)*	*Fry (4)*
1	Catfish	1.5	0.18	0.0334		4.31	
2	Trout	1	0.32	0.035		2.5	
3	Salmon	5	0.32	0.035		10	
4	Striped Bass	1.75	0.33	0.06		5	
5	Tilapia	1.75	0.32	0.035		2.5	
6	Other Finfish (except as listed)	1	0.32	0.035		2.5	
6-15	bass - smallmouth and largemouth	2.00					
6-19	Crappie	1.13					
6-20	Eel	4.62					
6-24	Paddlefish	2.00					
6-26	Perch	0.59					
6-27	Saugeye	1.00					
6-29	Sturgeon	45.00					
6-30	Sucker	2.19					
6-31	Sunfish (including bluegill and panfish)	0.25					
6-33	Walleye	3.00					
6-34	Whitefish	2.50					
6-35	Pike	4.63					
6-69	Shad (including threadfin)	2.50					
6-71	Charr	2.00					
6-73	Amberjack	75.00					
6-74	Bream	0.33					
6-75	Shell cracker	0.50					
7	Baitfish (except smelt)	0.01					
7-48	Smelt	0.19					
8	Ornamentals (except carp)	0.01					
8-17	Carp (includes koi, white amur)	4.00					
9	Shrimp	0.0444			6.6E-06	0.1	
10	Crawfish	0.0444				0.08	
11	Other Crustaceans	0.10					
12	Molluscan shellfish	0.10					
13	Other (except as listed)	1.00					
13-14	Alligators (and caimen)	13.00					
13-21	Frogs and tadpoles	0.13					
13-32	Turtles					3.5	.03

[1]The first number is the same as the categories listed in question 5 of the screener questionnaire. EPA assigned the second number to other species.

[2]For production reported in 'Other' units in question 5, EPA used 64 lbs/bushel; 1 lb/dollar; and other or unknown units were assumed to be counts.

Conversions for specific facilities: Misc. Invertebrates, 0.0000022 lbs/count; Bambooshark eggs and Seahorse seed stock, 0.001 lbs/count; Minnows, Mysid Shrimp, Silverside, and Waterfleas, 20 lbs/dollar.

Table A2.2. Total Biomass Calculations: Foodsize-to-Other Sizes Conversion Factors (when not specified in Table A2.1)

Size Code from Question 5 in the Screener	*Size*	*Food Size Multiplier*
1	Foodsize	1.0000
2	Stockers	0.1418
3	Fingerlings	0.0214
4	Fry	0.0014
5	Eggs	0.00001
6	Seed stock	0.0001
7	Brood size	3.4247
8	Other	0.1000

Table A2.3. Determination of Predominant Production Method: EPA's *Assumed* Hierarchy of Most to Least Common Production Method

Purpose	*Predominant Species*	*Most Common to Least Common Production Method*[1]
Screener Questionnaire Data Analysis [2] (See Attachment A-3)	Catfish	Ponds, Flow through, Recirculating, Other
	Trout	Flow through, Recirculating, Ponds, Net Pens
	Salmon	Net pens, Flow through, Recirculating
	Striped Bass	Ponds, Recirculating, Flow through
	Tilapia	Recirculating, Flow through, Ponds
Detailed Questionnaire Sample Selection[3]	Catfish	Ponds, Flow through, Net pens, Recirculating, Other
	Trout	Flow through, Ponds, Recirculating, Other, Net Pens, Floating aquaculture
	Salmon	Flow through, Net pens, Recirculating, Ponds, Other, Floating aquaculture
	Striped Bass	Ponds, Flow through, Recirculating, Net pens, Other
	Tilapia	Recirculating, Flow through, Ponds, Net pens, Other, Floating aquaculture
	Other Finfish	Ponds, Flow through, Recirculating, Net pens, Other, Floating aquaculture
	Baitfish	Ponds, Flow through, Recirculating
	Ornamentals	Ponds, Recirculating, Flow through, Other, Net pens, Floating aquaculture
	Shrimp	Ponds, Recirculating, Flow through, Other, Net pens, Floating aquaculture
	Crawfish	Ponds, Net pens, Flow through, Recirculating, Other
	Other crustaceans	Recirculating, Flow through, Floating aquaculture, Ponds
	Other	Ponds, Recirculating, Other, Flow through, Net pens, Floating aquaculture

[1] The production methods (e.g., 'Other) are from the choices provided in question 6 of the screener questionnaire.
[2] This hierarchy was based upon sources other than the screener questionnaire responses.
[3] This hierarchy is based upon a data analysis of the screener questionnaire responses. EPA acknowledges that floating aquaculture is unlikely to be used as a production method for certain species, and EPA plans additional review of these questionnaire responses.

Table A2.4. Revenue Calculations: Prices for Species by Size[1]

Species	***Size***	***Prices***	***USDA Table (page)*** [2]
Catfish	Foodsize	\$0.74/lb	8 (20)
	Stockers	\$1.03/lb	8 (21)
	Fingerlings/Fry	\$1.66/lb	8 (22)
	Brood Stock	\$0.91/lb	8 (19)
Trout	Foodsize	\$1.06/lb	9 (24)
	Stockers	\$2.29/lb	9 (25)
	Fingerlings	\$162.16/1000 fish eggs	9 (26)
Salmon	Foodsize (except Alaska)	\$2.00/lb	[3]
	Foodsize (Alaska)	\$0.23/lb	12 (39)
	Fingerlings/Fry	\$0.17/lb	12 (40)
Striped Bass	Foodsize	\$2.44/lb	12 (34)
	Fingerlings/Fry	\$0.26/lb	12 (35)
Tilapia	Foodsize	\$1.70/lb	12 (41)
	Fingerlings	\$0.11/fish	12 (42)

[1]EPA included *only* the listed species/size categories in its revenue calculations. Of those categories, EPA included only those responses that were reported in dollars sold, in pounds (applying the above conversion factors), or counts that could be converted to pounds using the conversion factors in Table A2.1.

[2]See USDA (2000).

[3] EPA adjusted the national average provided in Table 12 (p. 39) to obtain a value that did not include Alaska as follows:

(National total sales - Alaska sales)/(National total quantity - Alaska quantity)

= (\$103,583,000 - \$16,340,000)/(110,588,000 lbs - 70,129,000 lbs)

= \$2.16/lb which EPA rounded to \$2.00/lb

ATTACHMENT A-3 NATIONAL ESTIMATES BASED ON SCREENER QUESTIONNAIRES

The following tables provide national estimates (i.e., adjusted for non-response) of the responses to the screener questionnaires. Each table presents estimates for different types (‘domains’) of facilities, such as facilities in each USDA region or facilities using each production method. The facility domains are shown in the left column. Within each domain, Tables A3.1 through A3.8 show the number of facilities, percent of facilities, and total aquatic animal production. The total aquatic animal production is the total production of all species across all facilities in the domain. In contrast, Table A3.9 shows the total production of only the species used to define the domain rather than all species.

In some tables in this attachment, EPA has not presented the totals, because some facilities were placed in more than one category. For example, Table A3.7 provides the number of facilities and their production for each production method. Thus, if a facility has ponds and flow-through systems, the facility and its production would be counted under both production methods.

Table A3.1. USDA Region

	Number of Facilities		*Percent of Facilities*		*Production (thousands of pounds)*	
Region	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
NORTHEASTERN	452	18	14.7%	0.5%	74,673	15,890
SOUTHERN	1393	30	45.3%	0.7%	820,946	112,800
NORTH CENTRAL	485	18	15.8%	0.5%	27,138	5,978
WESTERN	664	20	21.6%	0.6%	258,830	96,884
TROPICAL	80	9	2.6%	0.3%	7,382	4,088
ALL	3075	46	100.0%		1,190,000	150,200

Table A3.2. Facility Type

	Number of Facilities		***Percent of Facilities***		***Production (thousands of pounds)***	
Facility Type	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Commercial	2384	44	77.5%	0.9%	1,060,000	146,700
Government	447	23	14.5%	0.7%	102,046	18,743
Research	67	9	2.2%	0.3%	1,738	724
Tribal	29	6	1.0%	0.2%	2,356	782
Other	147	14	4.8%	0.4%	20,762	5,266
ALL	3075	46	100.0%		1,190,000	150,200

Table A3.3. Predominant Species[1]

	Number of Facilities		***Percent of Facilities***		***Production, All Species (thousands of pounds)***	
Predominant Species	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Catfish	739	29	24.0%	0.9%	613,627	103,700
Trout	707	30	23.0%	0.9%	98,373	19,398
Salmon	197	13	6.4%	0.4%	111,756	21,466
Striped Bass	91	11	3.0%	0.3%	17,788	5,538
Tilapia	129	14	4.2%	0.4%	12,599	3,843
Other Finfish	376	21	12.2%	0.7%	31,542	9,313
Baitfish	116	13	3.8%	0.4%	8,371	2,220
Ornamentals	173	13	5.6%	0.4%	8,800	2,465
Shrimp	54	8	1.7%	0.3%	11,702	4,620
Crawfish	38	7	1.2%	0.2%	629	310
Other crustaceans	15	5	0.5%	0.1%	160	129
Molluscan shellfish	274	17	8.9%	0.5%	139,231	97,493
Other	168	13	5.5%	0.4%	134,390	53,166
ALL	3075	46	100.0%	0.0%	1,190,000	150,200

[1] The predominant species is the species with the largest production at a facility. Each facility has only one predominant species.

Table A3.4. Predominant Production Method

	Number of Facilities		*Percent of Facilities*		*Production (thousands of pounds)*	
Predominant Production Method	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Ponds	1561	38	50.8%	1.0%	763,380	109,500
Flow through raceways, ponds, or tanks	960	33	31.2%	0.9%	278,181	98,100
Recirculating systems	228	18	7.4%	0.6%	61,256	24,797
Net pens or cages	40	7	1.3%	0.2%	45,455	17,670
Floating aquaculture or bottom culture	233	17	7.6%	0.5%	37,564	11,463
Other	53	8	1.7%	0.3%	3,134	2,003
ALL	3075	46	100.0%	0.0%	1,190,000	150,200

Table A3.5. Water Discharge Status to POTW[1]

	Number of Facilities		*Percent of Facilities*		*Production (thousands of pounds)*	
Does water go to a POTW?	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Water leaves to POTW	127	13	4.1%	0.4%	9,242	3,583
Water leaves, not to POTW	1981	39	64.5%	1.0%	1,030,000	142,400
Water does not leave	954	35	31.0%	1.0%	147,904	39,775
No answer	13	4	0.4%	0.1%	474	324
ALL	3075	46	100.0%	0.0%	1,190,000	150,200

[1] The responses in the table combine the answers to questions 7 and 8 in the questionnaire.

Table A3.6. Water Discharge Status and NPDES Permits[1]

	Number of Facilities		*Percent of Facilities*		*Production (thousands of pounds)*	
Does water go to a POTW?	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Water leaves, facility has NPDES permit	541	27	17.6%	0.8%	278,103	98,129
Water leaves, No NPDES permit	1565	35	50.9%	1.0%	762,451	110,600
Water does not leave	954	35	31.0%	1.0%	147,904	39,775
No answer	14	5	0.5%	0.1%	511	324
ALL	3075	46	100.0%	0.0%	1,190,000	150,200

[1] The responses in the table combine the answers to questions 7 and 9 in the questionnaire.

Table A3.7. Production Method[1]

	Number of Facilities		*Percent of Facilities*		*Production (thousands of pounds)*	
Production Method	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Ponds	1860	43	60.7%	1.0%	786,298	104,400
Flow through raceways, ponds, or tanks	1358	36	44.3%	1.0%	394,321	101,100
Recirculating systems	610	26	19.9%	0.8%	129,575	29,385
Net pens or cages	262	17	8.6%	0.6%	71,454	19,388
Floating aquaculture or bottom culture	248	16	8.1%	0.5%	38,315	11,296
Other	155	13	5.1%	0.4%	19,432	9,026

[1] If a facility reports using more than one production method, the facility is included in the table totals for each production method used. Therefore the sum of the column for the number of facilities is greater than the number of facilities represented by the data, and the same is true for the production numbers. Thus, the totals are not presented.

Table A3.8. Species[1]

	Number of Facilities		Percent of Facilities		Production, All Species (thousands of pounds)	
Species	***Estimate***	***Standard error***	***Estimate***	***Standard error***	***Estimate***	***Standard error***
Catfish	901	30	29.3%	0.9%	637,211	99,896
Trout	818	28	26.6%	0.8%	120,600	23,065
Salmon	277	16	9.0%	0.5%	128,305	23,860
Striped Bass	155	13	5.1%	0.4%	24,817	6,168
Tilapia	178	15	5.8%	0.5%	24,005	7,236
Other Finfish	644	28	21.0%	0.8%	75,781	14,802
Baitfish	259	18	8.4%	0.6%	30,044	8,485
Ornamentals	267	19	8.7%	0.6%	24,031	7,881
Shrimp	73	10	2.4%	0.3%	12,957	4,623
Crawfish	83	9	2.7%	0.3%	12,353	6,430
Other crustaceans	24	6	0.8%	0.2%	293	170
Molluscan shellfish	303	18	9.9%	0.6%	140,308	96,204
Other	156	11	5.1%	0.4%	135,762	45,566

[1] If a facility produces more than one species, the facility is included in the table totals for each species produced. Therefore, the sum of the column for the number of facilities is greater than the number of facilities represented by the data, and the same is true for the production numbers. Each row provides the total production for all species at those facilities having the individual species in the left-hand column. See Table A3.9 for total production of just the individual species at those facilities.

Table A3.9. Species[1]

	Number of Facilities		Percent of Facilities		Production of Listed Species (thousands of pounds)	
Species	**Estimate**	**Standard error**	**Estimate**	**Standard error**	**Estimate**	**Standard error**
Catfish	901	30	29.3%	0.9%	613,569	99,705
Trout	818	28	26.6%	0.8%	97,381	20,420
Salmon	277	16	9.0%	0.5%	112,514	23,443
Striped Bass	155	13	5.1%	0.4%	17,848	5,228
Tilapia	178	15	5.8%	0.5%	13,771	3,870
Other Finfish	644	28	21.0%	0.8%	26,888	6,317
Baitfish	259	18	8.4%	0.6%	10,781	2,975
Ornamentals	267	19	8.7%	0.6%	10,054	2,828
Shrimp	73	10	2.4%	0.3%	11,634	4,501
Crawfish	83	9	2.7%	0.3%	754	309
Other crustaceans	24	6	0.8%	0.2%	131	98
Molluscan shellfish	303	18	9.9%	0.6%	139,321	96,225
Other	156	11	5.1%	0.4%	134,324	45,584

[1]The total production is the production for the species listed in the left column. See Table A3.8 for the total facility production which includes production of all other species at the facilities producing that species in the left column.

Table A3.10. For Selected Species, Number of Facilities by Predominant Production Method

Species	*Predominant Production Method*	*National Estimate*[1]	*Responses*
Catfish	Ponds	861.13	649
	Flow Through & Not(Ponds)	26.87	20
	Recirculating & Not(Ponds or Flow Through)	ND	ND
	Other, Not(Ponds, Flow Through, or Recirculating)	ND	ND
	All systems	900.91	679
Trout	Flow Through	735.07	569
	Recirculating & Not(Flow Through)	17.22	13
	Ponds & Not(Flow Through or Recirculating)	60.94	47
	Net Pens & Not(Flow Through, Recirculating, or Ponds)	ND	ND
	Missing Production Information	ND	ND
	All systems	818.40	633
Salmon	Net Pens	46.98	35
	Flow Through & Not(Net Pens)	219.25	166
	Recirculating & Not(Net Pens or Flow Through)	ND	ND
	Other, Not(Net Pens, Flow Through, or Recirculating)	ND	ND
	All systems	276.65	201
Shrimp	Ponds	55.57	42
	Recirculating & Not(Ponds)	ND	ND
	Flow through & Not(Ponds or Recirculating)	ND	ND
	All systems	72.53	55
Tilapia	Recirculating	119.42	90
	Flow Through & Not(Recirculating)	35.61	26
	Ponds & Not(Recirculating or Flow Through)	ND	ND
	Missing Production Information	ND	ND
	All systems	176.08	132
Sportfish (other Finfish)	Ponds	557.95	432
	Flow Through & Not(Ponds)	59.28	45
	Recirculating & Not(Ponds or Flow Through)	20.68	16
	Other, Not(Ponds, Flow Through, or Recirculating)	6.33	5
	All systems	644.24	498
Striped Bass/ Hybrid Striped Bass	Ponds	129.33	99
	Recirculating & Not(Ponds)	19.59	15
	Flow through & Not(Ponds or Recirculating)	ND	ND
	Other & Not(Ponds, Recirculating, or Flow Through)	ND	ND
	All systems	155.22	119
Alligator	All systems	41.12	31

[1]Sample sizes masked by ‘ND’ (‘Not Disclosed’) indicate there are five or fewer facilities for one or more of the production methods for that specie.

Table A3.11. Estimated Number of Facilities Covered by the Proposed Rule[1]

Predominant Production Method	*Species*	*Size*	*Revenue Classes*			
			Class 1 ≥ $20,000 and <$100,000	**Class 2 ≥ $100,000 and <$500,000**	**Class 3 ≥ $500,000**	**Total ≥ $20,000[4]**
Flow-through	Trout	Foodsize	92	44	13	149
		Stockers	139	131	39	309
	Salmon	All with $ value	44	52	38	133
	Striped Bass	All with $ value	n/a[2]	ND[3]	ND	ND
	Tilapia	All with $ value	n/a	ND	ND	9
Recirculating	Striped Bass	All with $ value	n/a	ND	ND	ND
	Tilapia	All with $ value	n/a	13	12	26
Net Pens	Salmon	All with $ value	ND	ND	19	32

[1] In the preamble to the proposed rule, EPA discusses six production size categories that correspond with the revenue classifications used in the 1998 USDA Census of Aquaculture (i.e., $1,000-$24,999; $25,000 - $49,999; $50,000 - $99,999; $100,000 - $499,999; $500,000 - $1,000,000; and >$1,000,000) to develop model facilities representing these size ranges for each species evaluated. Because small sample sizes for some revenue categories have small sample sizes, the national estimates are presented here. They are included in the non-public record as DCN50066CBI in Section 10.3.
[2] n/a: not applicable in the proposed rule
[3] ND: Sample sizes masked by 'ND' ('Not Disclosed') indicate there are five or fewer facilities for one or more of the classes in the production method/specie/size category
[4]Due to rounding, totals in this column may differ slightly from the sum of the numbers for the Classes.

APPENDIX B
ANALYTICAL METHODS AND NOMINAL QUANTITATION LIMITS

APPENDIX B
ANALYTICAL METHODS AND NOMINAL QUANTITATION LIMITS

The analytical methods described in this appendix were used to determine pollutant levels in wastewater samples collected by EPA at a number of aquatic animal production facilities (sampling efforts are described in Chapter 3). In developing the proposed rule, EPA sampled aquatic animal production facilities to determine the levels of *Aeromonas*, ammonia as nitrogen, 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), chloride, *E. coli*, *Enterococcus faecium*, fecal coliform, fecal streptococcus, 27 metals, *Mycobacterium marinum*, nitrate/nitrite, oil and grease (measured as hexane extractable material (HEM)), pH, settleable solids, semivolatile organics, sulfate, total chlorine, total coliform, total dissolved solids (TDS), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total orthophosphate, total phosphorus, total solids, total suspended solids (TSS), volatile organics, volatile residue, and whole effluent toxicity (WET). As explained in Chapters 2 and 8, EPA proposes to regulate only TSS, but it is also considering regulating total phosphorus and BOD_5 for some facilities.

Section B.1 of this appendix provides an explanation of nominal quantitation limits. Section B.2 describes the reporting conventions used by laboratories in expressing the results of the analyses. Section B.3 describes each analytical method and the nominal quantitation limits associated with each method.

B.1 NOMINAL QUANTITATION LIMITS

The nominal quantitation limit is the smallest quantity of an analyte that can be reliably measured with a particular method, using the typical (nominal) sample size. The protocols used for determination of nominal quantitation limits in a particular method depend on the definitions and conventions that EPA used at the time the method was developed. Printouts in Section 10 of the proposal record list the nominal quantitation limit as a 'baseline value.'[1] The nominal quantitation limits associated with the methods addressed in this section fall into five categories.

1. The first category pertains to EPA Methods 1624, 1625, and 1664, which define the minimum level (ML) as the lowest level at which the entire analytical system must give a recognizable signal and an acceptable calibration point for the analyte. These methods are described in Section B.3.1.

2. The second category pertains specifically to EPA Method 1620, and is explained in detail in Section B.3.2.

3. The third category pertains to the remainder of the chemical methods (classical wet chemistry analytes) in which a variety of terms are used to describe the lowest

[1] EPA used two different methods to analyze for ammonia as nitrogen and TKN, and only one method for the remaining pollutants of concern. The printout lists the nominal quantitation limit for the analytical method that was used most frequently for ammonia as nitrogen (Method 350.1) and TKN (Method 351.2).

level at which measurement results are quantitated. In some cases the methods date to the 1970s and 1980s when different concepts of quantitation were employed by EPA. These methods typically list a measurement range or lower limit of measurement. The terms differ by method and, as discussed in subsequent sections, the levels presented are not always representative of the lowest levels laboratories currently can achieve.

For those methods associated with a calibration procedure, the laboratories demonstrated through a low-point calibration standard that they were capable of reliable quantitation at method-specified (or lower) levels. In such cases, these nominal quantitation limits are operationally equivalent to the ML (although not specifically identified as such in the methods).

In the case of titrimetric or gravimetric methods, the laboratory adhered to the established lower limit of the measurement range published in the methods. Details of the specific methods are presented in Sections B.3.3 through B.3.18.

4. The fourth category pertains to all microbiological methods. This category pertains specifically to the membrane filtration test procedure and is explained in detail in Section B.3.19.

5. The fifth category pertains to all whole effluent toxicity methods. The whole effluent toxicity methods are explained in detail in Section B.3.20.

B.2 Analytical Results Reporting Conventions

The laboratories expressed results of the analyses either numerically or as not quantitated[2] for a pollutant in a sample. If the result is expressed numerically, then the pollutant was quantitated[3] in the sample. Most of the analytical chemistry data were reported as liquid concentrations in weight/volume units (e.g., micrograms per liter [µg/L]), except for settleable solids data., which were reported in volume/volume units (e.g., milliliters per liter [mL/L]), and the pH data, which were reported in "standard units" (SU). In the case of solid samples such as sediments, the results were provided in weight/weight units (e.g., milligrams per kilogram [mg/kg]). Bacteriological data generated using membrane filtration techniques were reported as colony forming units (CFU) per 100 mL volume of sample. Whole effluent toxicity data endpoints measured were lethality in 50% of the organisms (LC50) for the fathead minnow and the *Ceriodaphnia*, growth in the larval fathead minnow and *Selenastrum*, and the number of offspring produced in the *Ceriodaphnia.*

[2] Elsewhere in this document and in the preamble to the proposed rule, EPA may refer to pollutants as "not detected" or "non-detected." This appendix uses the term "not quantitated" or "non-quantitated" rather than non-detected.

[3] Elsewhere in this document and in the preamble to the proposed rule, EPA may refer to pollutants as "detected." This appendix uses the term "quantitated" rather than detected.

For example, for a hypothetical pollutant X, the result would be reported as "15 μg/L" when the laboratory quantitated the amount of pollutant X in the sample as being 15 μg/L. For the pollutants which could not be quantitated, the laboratories would report a "sample-specific quantitation limit,"[4] e.g., "<10 μg/L" when the analytical result indicated a value less than the sample-specific quantitation limit of 10 μg/L. In this example, the actual amount of pollutant X in that sample is between zero (i.e., the pollutant is not present) and 10 μg/L. The sample-specific quantitation limit for a particular pollutant is generally the smallest quantity in the calibration range that can be measured reliably in any given sample. If a pollutant is reported as non-quantitated in a particular wastewater sample, this does not mean that the pollutant is not present in the wastewater, merely that analytical techniques (whether because of instrument limitations, pollutant interactions, or other reasons) do not permit its measurement at levels below the sample-specific quantitation limit.

B.3 ANALYTICAL METHODS

EPA analyzed all of the aquatic animal production facility wastewater samples using methods identified in Table B-1. (As explained in Section Z, EPA is proposing to regulate only a subset of these analytes.) Except for the volatile and semivolatile organics and total organic carbon, EPA used either EPA methods from *Methods for Chemical Analysis of Water and Wastes* (MCAWW) or the American Public Health Association's *Standard Methods for the Examination of Water and Wastewater*. EPA methods are identified in the sections that follow by their method number, e.g., EPA Method 1624. Methods from *Standard Methods for the Examination of Water and Wastewater* are prefaced by "SM." All of the chemical methods cited from Standard Methods (SM) are from the 18th edition; the biological methods cited from Standard Methods are from the 20th edition.

In analyzing samples, EPA generally used analytical methods approved at 40 CFR Part 136 for compliance monitoring or methods that had been in use by EPA for decades in support of effluent guidelines development. Exceptions for use of non-approved methods are explained in the method-specific subsections that follow. All EPA-proposed limitations or standards are based upon data generated by methods approved at 40 CFR Part 136.

Each of the following sections states whether the method is listed at 40 CFR Part 136 (even if the pollutant was not proposed for regulation), provides a short description of the method, and identifies the nominal quantitation limit. Methods listed at 40 CFR Part 136 are approved for use in wastewater compliance monitoring under the NPDES process.

[4] Elsewhere in this document and in the preamble to the proposed rule, EPA may refer to a "sample-specific quantitation limit" as a "sample-specific detection limit" or, more simply, as a "detection limit."

Table B-1 Analytical Methods

Analyte	Method	CAS Number	Nominal Quantitation Limit	Unit
Aeromonas	1605	C2101	1.00	CFU/100 mL
Ammonia as Nitrogen	350.1	7664417	0.01	mg/L
	350.2	7664417	0.05	mg/L
	4500-NH_3 H	7664417	0.02	mg/L
BOD_5	405.1	C003	2.0	mg/L
Ceriodaphnia Dubia Chronic	1002.0	N/A	100	%
COD	410.1	C004	5.0	mg/L
	410.4	C004	3.0	mg/L
	5220C	C004	50.0	mg/L
Chloride	325.1	16887006	1.0	mg/L
	325.3	16887006	1.0	mg/L
	4500Cl^- B	16887006	1.5	mg/L
E. coli	600-R-00-013	68583222	1.00	CFU/100 mL
Enterococcus Faecium	9230C	68876788	100.00	CFU/100 mL
Fathead Minnow	1000.0	N/A	100	%
Fecal Coliform	9222D	C2106	1.00	CFU/100 mL
Fecal Streptococcus	9230C	C2107	1.00	CFU/100 mL
HEM	1664	C036	5.0	mg/L
Metals	1620	†		
Mycobacterium marinum	9260M	C2119	4.00	CFU/100 mL
Nitrate/Nitrite	353.1	C005	0.01	mg/L
	353.3	C005	0.01	mg/L
	4500-NO_3 E	C005	0.01	mg/L
Oil and Grease	5520E	C036	5.0	mg/L
Orthophosphate	365.2	C034	0.01	mg/L
pH	150.1	C006		SU
	9045C	C006		SU
Selenastrum Growth Test	1003.0	N/A	100	%
Semivolatile Organics	1625	†		
Settleable Solids	2540F	N/A	0.1	mL/L
Sulfate	375.3	14808798	10.0	mg/L
	375.4	14808798	1.0	mg/L
Total Chlorine	Test Strip	7782505	0.05	mg/L
Total Coliform	600-R-00-013	E10606	1.0	CFU/100 mL
Total Dissolved Solids	160.1	C010	10.0	mg/L
Total Kjeldahl Nitrogen	351.2	C021	0.5	mg/L

Analyte	Method	CAS Number	Nominal Quantitation Limit	Unit
	351.3	C021	1.0	mg/L
	4500-N_{org} C	C021	0.02	mg/L
Total Organic Carbon	415.1	C012	1.0	mg/L
	Lloyd Kahn	C012	100	mg/kg
Total Phosphorus	365.2	14265442	0.01	mg/L
Total Suspended Solids	160.2	C009	4.0	mg/L
Volatile Organics	1624	†		
Volatile Residue	160.4	C030	10.0	mg/L

N/A There is no CAS Number for this analyte.† The method analyzed a number of pollutants.

B.3.1 EPA Methods 1624, 1625, and 1664 (Volatile Organics, Semivolatile Organics, and HEM)

Laboratories used EPA Methods 1624, 1625, and 1664 to measure volatile organics, semivolatile organics, and *n*-hexane extractable material (HEM). EPA Methods 1624, 1625, and 1664 are approved at 40 CFR Part 136.

These methods use the minimum level (ML) concept for quantitation of pollutants. The ML is defined as the lowest level at which the entire analytical system must give a recognizable signal and an acceptable calibration point for the analyte. When an ML is published in a method, the Agency has demonstrated that the ML can be achieved in at least one well-operated laboratory. When that laboratory or another laboratory uses that method, the laboratory is required to demonstrate, through calibration of the instrument or analytical system, that it can achieve pollutant measurements at the ML.

The nominal quantitation values are equal to the MLs listed in the methods for each analyte. The MLs for majority of volatile and semivolatile organics are 10 µg/L, with a small number of higher values for pollutants that are more difficult to analyze. The ML for HEM determined by EPA Method 1664 is 5 mg/L.

B.3.2 EPA Method 1620 (Metals)

Laboratories used EPA Method 1620 to measure the concentrations of 27 metals. While EPA Method 1620 is not listed at 40 CFR Part 136, it represents a consolidation of the analytical techniques in several 40 CFR 136-approved methods such as EPA Method 200.7 (inductively coupled plasma atomic emission (ICP) spectroscopy of trace elements) and Method 245.1 (mercury cold vapor atomic absorption technique). EPA Method 1620 was developed specifically for the effluent guidelines program. This method includes more metal analytes than are listed in the approved metals methods and contains quality control requirements that are at least as stringent as the approved methods.

EPA Method 1620 employs the concept of an instrument detection limit (IDL). The IDL is defined as “the smallest signal above background noise that an instrument can detect reliably.” Data reporting practices for EPA Method 1620 analyses follow conventional metals reporting practices used in other EPA programs, in which values are required to be reported at or above the IDL. In applying EPA Method 1620, IDLs are determined on a quarterly basis by each analytical laboratory and are, therefore, laboratory-specific and time-specific.

Although EPA Method 1620 contains MLs, these MLs pre-date EPA's recent refinements of the ML concept described earlier. The ML values associated with EPA Method 1620 are based on a consensus reached between EPA and laboratories during the 1980s regarding levels that could be considered reliable quantitation limits when using EPA Method 1620. These limits do not reflect advances in technology and instrumentation since the 1980s. Consequently, the IDLs were used as the lowest values for reporting purposes, with the general understanding that reliable results can be produced at or above the IDL. The nominal quantitation values are the MLs listed in EPA Method 1620, except for two instances. The published ML for lead in EPA Method 1620 is 5 µg/L for graphite furnace atomic absorption (GFAA) spectroscopy analysis. However, for the purposes of this effluent guideline study, EPA determined that it was not necessary for the laboratories to measure lead to such low levels, and permitted the analysis of lead by ICP spectroscopy. Consequently, the nominal quantitation limit for lead was adjusted to 50 µg/L, the ML for the ICP method. Boron has an ML of 10 µg/L, but historical information indicates that laboratories could not reliably achieve this low level. As a result, EPA only required laboratories to measure values at 100 µg/L and above; this is the nominal quantitation limit used here.

B.3.3 EPA Methods 350.1 and 350.2, and SM 4500H (Ammonia as Nitrogen)

Ammonia, as nitrogen, was measured using EPA Methods 350.1 and 350.2, and SM 4500H, all of which are approved at 40 CFR Part 136. Methods 350.1 and SM 4500H are automated methods using a continuous flow analytical system with a phenate/hypochlorite color reagent that reacts with ammonia to form indophenol blue that is proportional to the ammonia concentration. Method 350.2 utilizes either colorimetric, titrimetric, or electrode procedures to measure ammonia.

Method 350.1 has a lower measurement range limit of 0.01 mg/L. SM 4500H has a lower measurement range limit of 0.02 mg/L. Method 350.2 has a lower measurement range limit of 0.20 mg/L for the colorimetric and electrode procedures, and a lower measurement range limit of 1.0 mg/L for the titrimetric procedure.

B.3.4 EPA Method 405.1 (Biochemical Oxygen Demand)

Biochemical oxygen demand (BOD_5) was measured using EPA Method 405.1, which is approved at 40 CFR Part 136. The sample and appropriate dilutions are incubated for five days at 20°C in the dark. The reduction in dissolved oxygen concentration during the incubation period is the measure of the biochemical oxygen demand.

The nominal quantitation limit for Method 405.1, which is expressed in the method as the lower limit of the measurement range, is 2 mg/L.

B.3.5 EPA Methods 410.1 and 410.4, and SM 5220C (Chemical Oxygen Demand)

Chemical oxygen demand (COD) was measured using EPA Methods 410.1 and 410.4, and SM 5220C, all of which are approved at 40 CFR Part 136. Methods 410.1 and SM 5220C are titrimetric procedures designed to measure mid-level concentrations of COD and are associated with a nominal quantitation limit of 50 mg/L. Method 410.4 is a spectrophotometric procedure that measures COD and is associated with a nominal quantitation limit of 3 mg/L.

B.3.6 EPA Methods 325.1 and 325.3, and SM 4500B (Chloride)

Chloride was measured using Methods 325.1 and 325.3, and SM 4500B, all of which are approved at 40 CFR Part 136. Method 325.1 is an automated colorimetric method that uses a ferricyanide reagent color for development. Method 325.3 is a titrimetric procedure that uses mercuric nitrate as the titrant. SM 4500B is also a titrimetric procedure, but it uses silver nitrate as the titrant.

Methods 325.1 and 325.3 measure concentrations greater than 1 mg/L, so the nominal quantitation limit is 1 mg/L. SM 4500B measures concentrations greater than 1.5 mg/L, so the nominal quantitation limit is 1.5 mg/L.

B.3.7 EPA Methods 353.1 and 353.3, and SM 4500E (Nitrate/Nitrite)

Nitrate/nitrite was measured using EPA Methods 353.1 and 353.3, and SM 4500E, all of which are approved at 40 CFR Part 136. Method 353.1 is based on a colorimetric technique (i.e., adding reagents to a sample that form a colored product when they react with the nitrate/nitrite and measuring the intensity of the colored product). Method 353.1 uses hydrazine to reduce the nitrate (NO_3) present in the sample to nitrite (NO_2). Methods 353.3 and SM 4500E use granulated copper cadmium to reduce nitrate to nitrite. The nitrite is determined by reaction with sulfanilamide and coupling with N-(1-naphthyl)-ethylene diamine dihydrochloride to form a highly colored azo dye that is measured spectrophotometrically.

The nominal quantitation limit associated with Methods 353.1, 353.3, and SM 4500E is 0.01 mg/L.

B.3.8 SM 5520E (Oil and Grease)

SM 5520E was used to measure oil and grease in the sediment samples from the aquatic animal production facilities because EPA Method 1664 is only applicable to aqueous samples. SM5520E is not approved at 40 CFR Part 136 because this method is applicable only to solid samples and not wastewater samples. SM 5520E is a gravimetric method in which the sediment is dried, the oil and grease is extracted with *n*-hexane, and the extract is weighed to obtain the concentration of oil and grease in the sample. The only difference between SM5520E and Method 1664 is the preparation of the sample for extraction. The solid sample is dried and magnesium sulfate added before extraction. There is no nominal quantitation limit associated with this method.

B.3.9 EPA Methods 150.1 and 9045C (pH)

EPA Method 150.1 was used to analyze aqueous samples. Method 150.1 is approved at 40 CFR Part 136. Method 9045C, from *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), was used to analyze the sediment samples. Although Method 9045C is not approved at 40 CFR Part 136, it is approved for analyses of solid samples under the RCRA regulations at 40 CFR Part 261.

For Method 150.1, the pH of a sample is determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. For Method 9045C, the sample is mixed with reagent water and the pH of the resulting aqueous solution is measured electrometrically.

There are no nominal quantitation limits for either Method 150.1 or 9045C.

B.3.10 SM 2540F (Settleable Solids)

Settleable solids was determined by SM 2540F in the field by the samplers at the aquatic animal production facilities. SM 2540F is a volumetric method which uses an Imhoff cone. An Imhoff cone is filled to the 1-L mark with a well-mixed wastewater sample. The solids in the sample are allowed to settle in the cone for 45 minutes. The sample is agitated near the sides of the cone with a rod or by spinning and allowed to settle for an additional 15 minutes. The volume of the settleable solids in the cone is recorded as milliliters per liter (mL/L).

SM 2540F is approved at 40 CFR Part 136 under "residue-settleable." The method lists a lower limit of the measurement range of 0.1 mL/L; this value is also the nominal quantitation limit.

B.3.11 EPA Methods 375.3 and 375.4 (Sulfate)

Sulfate was measured by EPA Methods 375.3 and 375.4, both of which are approved at 40 CFR Part 136. Method 375.3 is a gravimetric method that measures the amount of barium sulfate formed by reacting the sample with barium chloride. Method 375.4 measures the turbidity created by the insoluble barium sulfate in solution. A dispersant/buffer is added to the solution to aid in creating uniform suspension of the barium sulfate.

The nominal quantitation limit (also the lower limit of the measurement range) for Method 375.3 is 10 mg/L. The nominal quantitation limit for Method 375.4 is 1 mg/L.

B.3.12 Test Strip Kit (Total Chlorine)

Total chlorine was determined by SenSafe™ total chlorine test strips in the field by the samplers at the aquatic animal production facilities. SenSafe™ total chlorine test strips range in sensitivity from 0.05 mg/L to 80 mg/L. The test strip from each sample is compared to a color chart to determine the result of the total chlorine.

B.3.13 EPA Method 160.1 (Total Dissolved Solids)

Total dissolved solids (TDS) were measured by EPA Method 160.1, which is approved at 40 CFR 136 under "residue-filterable." Method 160.1 is a gravimetric method with a lower limit of the measurement range of 10 mg/L; this value is also the nominal quantitation limit.

B.3.14 EPA Methods 351.2 and 351.3, and SM 4500C (Total Kjeldahl Nitrogen)

Total Kjeldahl nitrogen (TKN) was measured by EPA Methods 351.2 and 351.3, and SM 4500C, all of which are approved at 40 CFR Part 136. For Method 351.2, the sample is digested in a strong acid and a metal ion catalyst solution, taken to dryness, then reconstituted with an alkaline solution. The ammonia is the solution is determined by indophenol colorimetry using an automated continuous flow system. For Methods 351.3 and SM 4500C, the sample digestion is performed using a strong acid reagent with a metal ion catalyst. After the digestion period is complete, the solution is made alkaline and the ammonia in the digestate is distilled off into a borate buffer solution. Methods 351.3 and SM 4500C offer three different quantitation technique options for determining the ammonia concentration: titrimetric, iodide colorimetric, or NH_3 ion selective electrode.

The nominal quantitation limit (also the lower limit of the measurement range) for Method 351.2 is 0.1 mg/L. The nominal quantitation limit for Method 351.3 is 0.05 mg/L and the nominal quantitation limit for SM 4500C is 0.02 mg/L.

B.3.15 EPA Method 415.1 and the "Lloyd Kahn" Procedure (Total Organic Carbon)

Total organic carbon (TOC) was determined by EPA Method 415.1 and the "Lloyd Kahn" procedure. Method 415.1 is a combustion (or oxidation) method with a lower limit of the measurement range is 1 mg/L; this value is also the nominal quantitation limit. The Lloyd Kahn procedure is similar to Method 415.1, but allows for a pyrolitic method that uses an elemental analyzer to determine carbon concentration. The nominal quantitation limit for the Lloyd Kahn procedure is 100 mg/kg.

Method 415.1 is approved at 40 CFR Part 136 and was used to analyze aqueous samples. However, this method only applies to aqueous samples. Therefore, the Lloyd Kahn procedure was used to analyze the solid samples. The Lloyd Kahn procedure applies only to solid samples and therefore is not approved at 40 CFR Part 136.

B.3.16 EPA Method 365.2 (Total Orthophosphate and Total Phosphorus)

Total orthophosphate and total phosphorus were measured by EPA Method 365.2, which is approved at 40 CFR Part 136. Total phosphorus represents all of the phosphorus present in the sample, regardless of form, as measured by the persulfate digestion procedure. Total orthophosphate represents the inorganic phosphorus (PO_4) in the sample determined by the direct colorimetric analysis procedure.

Method 365.2 is a colorimetric method and measures concentrations greater than 0.01 mg/L, which is also the nominal quantitation limit, for total orthophosphate and total phosphorus.

B.3.17 EPA Method 160.2 (Total Suspended Solids)

Total suspended solids (TSS) were determined by EPA Method 160.2, which is approved at 40 CFR Part 136 as "residue-nonfiltrable." Method 160.2 is a gravimetric method with a lower limit of the measurement range of 4 mg/L; this value is also the nominal quantitation limit.

B.3.18 EPA Method 160.4 (Volatile Residue)

Volatile residue was determined by EPA Method 160.4, which is approved at 40 CFR Part 136. Method 160.4 is a gravimetric and ignition method with a lower limit of the measurement range of 10 mg/L; this value is also the nominal quantitation limit.

B.3.19 EPA 600-R-00-013, SM 9222D, SM 9230C, EPA 1605, SM 9260M (total coliform, fecal coliform, *E. coli*, fecal Streptococcus, *Enterococcus faecium*, *Aeromonas*, and *Mycobacterium marinum*)

Laboratories measured the densities of total coliform, fecal coliform, *E. coli*, fecal Streptococcus, *Aeromonas*, and *Enterococcus faecium* using membrane filtration methods specified in Standard Methods. EPA used methods approved at 40 CFR Part 136 for fecal coliform (SM9222D), fecal streptococcus (SM9230C), and *Enterococcus faecium* (SM 9230C). There are no 40 CFR Part 136-approved methods for *E. coli*, *Aeromonas*, and *Mycobacterium marinum*. However, the method employed for *E. coli* was proposed for ambient water monitoring on August 30, 2001 (66 FR 169, pages 45811-45829).

1. **Total coliforms and *E. coli*** (EPA 600-R-00-013). Samples are filtered utilizing 0.45-μm filters, placed onto MI agar, and incubated for 24 ± 2 hours. Plates are read using ambient light and UV light to obtain total coliform and *E. coli* counts. Blue colonies are recorded as positive for *E. coli* and all colonies that fluoresce under UV light are recorded as total coliforms.

2. **Fecal coliforms (9222D)**. Samples are filtered and placed onto mFC plates and incubated for 24 ± 2 hours in a water bath at 44.5°C ± 0.2°C. All blue colonies are considered positive for fecal coliforms.

3. **Fecal streptococcus (SM 9230C)**. Samples are filtered and placed onto mEnterococcus plates and incubated for 48 ± 3 hours. All light and dark red colonies are considered positive for fecal streptococcus.

4. ***Aeromonas* (EPA Method 1605)**. Samples are filtered and placed onto ADA-V plates. All yellow colonies are isolated on nutrient agar and confirmed as *Aeromonas* if they are oxidase- and indole-positive and are able to ferment trehalose.

5. ***Enterococcus faecium* (SM 9230C)**. Samples are filtered, placed onto mE agar, and incubated for 48 ± 3 hours. All filters with growth are transferred to EIA plates and incubated for an additional 20 minutes. All pink to red colonies on mE agar that produced a black or reddish brown precipitate on EIA agar are considered positive for *Enterococcus*. This effluent guideline study required that five positive colonies from each plate be submitted to biochemical identification to speciate and determine the levels of *Enterococcus faecium*.

6. ***Mycobacterium marinum* (SM9260M)**. Samples are screened for acid-fast bacteria prior to culturing. If acid-fast bacteria are present, the samples are decontaminated to remove organisms that may out-compete and overgrow the mycobacterium. After decontamination the samples are cultured in duplicate and incubated for 3-8 weeks at 37° C. Biochemical tests were then used to speciate the *Mycobacterium*.

The nominal quantitation limits for all the microbiological methods, except *Enterococcus faecium* and *Mycobacterium marinum*, are 1 CFU/100 mL. The nominal quantitation limit for *Enterococcus faecium* is 100 CFU/100 mL; the nominal quantitation limit for *Mycobacterium marinum* is 4 CFU/100 mL. The nominal quantitation limits are based on the actual sample volume filtered. For example, if a 100-mL volume is filtered, the nominal quantitation limit would be 1 CFU/100 mL. If a 10-mL volume is filtered, the nominal quantitation limit would be 10 CFU/100 mL.

Table II at 40 CFR 136.3 specifies holding times of six hours for some pathogens. In collecting data supporting this proposed rule, EPA measured counts in samples that had been retained longer than the six hours specified in Table II. In its data review narratives (located in Section X of the proposal record), EPA has identified those samples that were retained longer than eight hours at the laboratory (includes the six-hour holding time allotted for delivery to the laboratory plus an additional two hours at the laboratory). Standard Method 9221E, the 40 CFR Part 136-approved method for fecal coliform, states that "Water treatment and other adverse environmental conditions often place great stress on indicator bacteria, resulting in an extended lag phase before logarithmic growth takes place." EPA is currently conducting a holding time study to assess potential changes in pathogen concentrations in effluents over time (i.e., 8, 24, 30, and 48 hours after sample collection). This study will evaluate total and fecal coliforms, *Escherichia coli*, *Aeromonas* species, and fecal streptococci for both the aquatic animal production facilities and meat products industrial effluents. Additionally, *Enterococcus faecium* was analyzed in aquaculture effluents, and *Salmonella* was analyzed in meat products industry effluents.

EPA is conducting this holding time study for possible revisions to Table II. EPA notes that if the holding time can be extended to longer periods, overnight shipping of samples would be possible for compliance monitoring. However, EPA has not proposed any limitations and standards for these analytes. The study plan for the holding time study is located at DCN 50022 in Section 10.2 of the proposal record. In the forthcoming NODA, EPA will provide the data collected during the study and EPA's evaluation of the results.

B.3.20 EPA Methods 1003.0, 1000.0, and 1002.0 (*Selenastrum* growth test, Fathead Minnow Chronic, and *Ceriodaphnia Dubia* Chronic)

Whole effluent toxicity was measured using a suite of methods including the *Selenastrum* growth test (EPA Method 1003.0), the fathead minnow larval survival and growth test (EPA Method 1000.0), and *Ceriodaphnia dubia* survival and reproductive test (EPA Method 1002.0). All three methods are listed in Table 1A at 40 CFR Part 136. Endpoints measured were lethality in 50% of the organisms (LC50) for the fathead minnow and the *Ceriodaphnia*, growth in the larval fathead minnow and *Selenastrum*, and the number of offspring produced in the *Ceriodaphnia.*

1. **Method 1003.0: *Selenastrum* growth test**. A population of the green algae, *Selenastrum capricornutum*, is exposed in a static system to a series of effluent concentrations for 96 hours. The response of the population is measured in terms of changes in cell density (cell counts per mL). The toxicity of the effluent is indicated by increases or decreases in algal growth in response to nutrients and toxicants, compared to a control group (unexposed) of algae.

   The test is run using a 50-mL aliquot of effluent solution in a 250-mL flask. The effluent solutions are 6.25%, 12.5%, 25%, 50%, and 100% effluent. Each effluent concentration is run in five replicates. Each flask is inoculated with 10,000 cells per mL and allowed to grow during a 96-hour time period. During this time, the flasks are swirled twice daily to homogenize the cells within the flasks to allow for optimum growth. After the 96 hours, cells are counted from each of the flasks by taking an aliquot and counting the cells under a microscope using an approved cell counting method.

2. **Method 1000.0: Fathead minnow chronic**. Larva of the fathead minnow, *Pimephales promelas*, are exposed to different concentrations of effluent for seven days in a static renewal system. Test results are based on survival and weight of the larvae. The toxicity of the effluent is indicated by changes in the survival rate and decreases in the growth of the larvae that survive the testing period, compared to a control group (unexposed) of larvae.

   The test is run using a 250-mL aliquot of effluent solution in a 500-mL beaker. The effluent solutions are 6.25%, 12.5%, 25%, 50%, and 100% effluent. Each effluent concentration is run in 4 replicates, each containing 10 minnows, with an initiation age of less than 24 hours old. Daily observations are made to record the number of surviving minnows when the effluent solution is renewed. At 96 hours the test is terminated, the final number of surviving minnows is recorded, and the surviving minnows are preserved in 70% ethanol, then dried and weighed. The survival of minnows at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as an LC50. The weight of the surviving minnows at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as the inhibition concentration with a 25% effect (IC25).

3. **Method 1002.0: *Ceriodaphnia dubia* chronic**. *Ceriodaphnia dubia* are exposed in a static renewal system to different concentrations of effluent until 60% of surviving control organisms have three broods of offspring. Test results are based on survival and reproduction. If the test is conducted properly, the surviving control organisms should produce 15 or more offspring in three broods.

   The test is run using a 15-mL aliquot of effluent solution in a 30-mL beaker. The effluent solutions are 6.25%, 12.5%, 25%, 50%, and 100% effluent. Each effluent concentration is run in 10 replicates containing 1 female with an initiation age of less than 24 hours old. Daily observations are made to record the number of surviving organisms and the number of offspring when the effluent solution is renewed. When 60% of the surviving females produce 3 broods, the test is terminated. The survival of organisms at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as an LC50. The number of offspring produced by the surviving organisms at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as an IC25.

APPENDIX C
DAILY INFLUENT AND EFFLUENT DATA FOR POLLUTANTS OF CONCERN

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ALUMINUM	7429905	200	UG/L	6297C	1	SP-12	1940.000	NC	SP13+14	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297C	2	SP-12	2210.000	NC	SP13+14	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297C	3	SP-12	2950.000	NC	SP13+14	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297C	4	SP-12	720.000	NC	SP13+14	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297C	5	SP-12	2610.000	NC	SP13+14	50.000	ND	2205.664	50.000	97.73
ALUMINUM	7429905	200	UG/L	6297D	1	SP-4	50.000	ND						
ALUMINUM	7429905	200	UG/L	6297D	2	SP-4	50.000	ND						
ALUMINUM	7429905	200	UG/L	6297D	3	SP-4	50.000	ND						
ALUMINUM	7429905	200	UG/L	6297D	4	SP-4	50.000	ND						
ALUMINUM	7429905	200	UG/L	6297D	5	SP-4	50.000	ND				50.000		
ALUMINUM	7429905	200	UG/L	6297F	1				SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297F	2				SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297F	3				SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297F	4				SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297F	5				SP2+3	50.000	ND		50.000	
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297C	1	SP-12	1.160	NC	SP13+14	1.690	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297C	2	SP-12	1.940	NC	SP13+14	0.840	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297C	3	SP-12	4.200	NC	SP13+14	1.070	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297C	4	SP-12	1.520	NC	SP13+14	1.305	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297C	5	SP-12	1.440	NC	SP13+14	1.580	NC	2.075	1.309	36.90
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297D	1	SP-4	0.050	ND						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297D	2	SP-4	0.050	ND						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297D	3	SP-4	0.050	ND						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297D	4	SP-4	0.050	ND						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297D	5	SP-4	0.050	ND				0.050		
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297F	1				SP2+3	0.140	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297F	2				SP2+3	0.120	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297F	3				SP2+3	0.120	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297F	4				SP2+3	0.100	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297F	5				SP2+3	0.095	NC		0.115	
BARIUM	7440393	200	UG/L	6297C	1	SP-12	317.000	NC	SP13+14	23.000	NC			
BARIUM	7440393	200	UG/L	6297C	2	SP-12	288.000	NC	SP13+14	22.600	NC			
BARIUM	7440393	200	UG/L	6297C	3	SP-12	327.000	NC	SP13+14	22.950	NC			
BARIUM	7440393	200	UG/L	6297C	4	SP-12	249.000	NC	SP13+14	23.150	NC			
BARIUM	7440393	200	UG/L	6297C	5	SP-12	382.000	NC	SP13+14	23.500	NC	313.402	23.040	92.65
BARIUM	7440393	200	UG/L	6297D	1	SP-4	21.900	NC						
BARIUM	7440393	200	UG/L	6297D	2	SP-4	21.400	NC						
BARIUM	7440393	200	UG/L	6297D	3	SP-4	21.900	NC						
BARIUM	7440393	200	UG/L	6297D	4	SP-4	21.200	NC						
BARIUM	7440393	200	UG/L	6297D	5	SP-4	22.200	NC				21.721		
BARIUM	7440393	200	UG/L	6297F	1				SP2+3	22.650	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BARIUM	7440393	200	UG/L	6297F	2				SP2+3	21.650	NC			
BARIUM	7440393	200	UG/L	6297F	3				SP2+3	21.800	NC			
BARIUM	7440393	200	UG/L	6297F	4				SP2+3	21.500	NC			
BARIUM	7440393	200	UG/L	6297F	5				SP2+3	21.500	NC		21.821	
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297C	1	SP-12	369.000	RC	SP13+14	15.700	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297C	2	SP-12	377.000	RC	SP13+14	11.200	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297C	3	SP-12	380.000	RC	SP13+14	14.200	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297C	4	SP-12	184.000	RC	SP13+14	16.550	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297C	5	SP-12	380.000	RC	SP13+14	14.800	NC	343.432	14.529	95.77
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297D	1	SP-4	4.000	ND						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297D	2	SP-4	4.000	ND						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297D	3	SP-4	4.000	ND						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297D	4	SP-4	6.000	ND						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297D	5	SP-4	4.000	ND				4.400		
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297F	1				SP2+3	3.050	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297F	2				SP2+3	4.400	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297F	3				SP2+3	4.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297F	4				SP2+3	6.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297F	5				SP2+3	2.200	NC		3.944	
BORON	7440428	100	UG/L	6297C	1	SP-12	105.000	NC	SP13+14	48.000	NC			
BORON	7440428	100	UG/L	6297C	2	SP-12	226.000	NC	SP13+14	51.600	NC			
BORON	7440428	100	UG/L	6297C	3	SP-12	216.000	NC	SP13+14	48.950	NC			
BORON	7440428	100	UG/L	6297C	4	SP-12	231.000	NC	SP13+14	46.650	NC			
BORON	7440428	100	UG/L	6297C	5	SP-12	136.000	NC	SP13+14	49.500	NC	185.838	48.947	73.66
BORON	7440428	100	UG/L	6297D	1	SP-4	48.500	NC						
BORON	7440428	100	UG/L	6297D	2	SP-4	47.000	NC						
BORON	7440428	100	UG/L	6297D	3	SP-4	46.200	NC						
BORON	7440428	100	UG/L	6297D	4	SP-4	46.600	NC						
BORON	7440428	100	UG/L	6297D	5	SP-4	47.400	NC				47.142		
BORON	7440428	100	UG/L	6297F	1				SP2+3	51.000	NC			
BORON	7440428	100	UG/L	6297F	2				SP2+3	50.000	NC			
BORON	7440428	100	UG/L	6297F	3				SP2+3	48.000	NC			
BORON	7440428	100	UG/L	6297F	4				SP2+3	48.900	NC			
BORON	7440428	100	UG/L	6297F	5				SP2+3	45.000	NC		48.592	
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297C	1	SP-12	5130.000	NC	SP13+14	56.300	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297C	2	SP-12	1800.000	RC	SP13+14	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297C	3	SP-12	732.000	RC	SP13+14	54.950	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297C	4	SP-12	870.000	RC	SP13+14	52.300	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297C	5	SP-12	480.000	RC	SP13+14	30.000	NC	1896.347	43.279	97.72
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297D	1	SP-4	20.000	ND						

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297D	2	SP-4	20.000	ND						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297D	3	SP-4	20.000	ND						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297D	4	SP-4	20.000	ND						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297D	5	SP-4	20.000	ND				20.000		
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297F	1				SP2+3	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297F	2				SP2+3	25.200	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297F	3				SP2+3	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297F	4				SP2+3	30.100	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297F	5				SP2+3	20.000	ND		23.104	
COPPER	7440508	25	UG/L	6297C	1	SP-12	371.000	NC	SP13+14	5.000	ND			
COPPER	7440508	25	UG/L	6297C	2	SP-12	233.000	NC	SP13+14	5.000	ND			
COPPER	7440508	25	UG/L	6297C	3	SP-12	267.000	NC	SP13+14	5.000	ND			
COPPER	7440508	25	UG/L	6297C	4	SP-12	68.200	NC	SP13+14	5.000	ND			
COPPER	7440508	25	UG/L	6297C	5	SP-12	406.000	NC	SP13+14	5.000	ND	296.819	5.000	98.32
COPPER	7440508	25	UG/L	6297D	1	SP-4	5.000	ND						
COPPER	7440508	25	UG/L	6297D	2	SP-4	5.000	ND						
COPPER	7440508	25	UG/L	6297D	3	SP-4	5.000	ND						
COPPER	7440508	25	UG/L	6297D	4	SP-4	5.000	ND						
COPPER	7440508	25	UG/L	6297D	5	SP-4	5.000	ND				5.000		
COPPER	7440508	25	UG/L	6297F	1				SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297F	2				SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297F	3				SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297F	4				SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297F	5				SP2+3	5.000	ND		5.000	
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297C	1	SP-12	900.000	NC	SP13+14	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297C	2	SP-12	345.000	NC	SP13+14	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297C	3	SP-12	451.000	NC	SP13+14	20.800	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297C	4	SP-12	247.000	NC	SP13+14	16.300	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297C	5				SP13+14	44.767	NC	501.351	19.070	96.20
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297D	1	SP-4	5.000	ND						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297D	2	SP-4	5.000	ND						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297D	3	SP-4	7.133	NC						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297D	4	SP-4	13.187	NC						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297D	5	SP-4	5.410	ND				7.345		
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297F	1				SP2+3	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297F	2				SP2+3	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297F	3				SP2+3	5.893	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297F	4				SP2+3	15.030	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297F	5				SP2+3	5.510	ND		7.789	
HEXANOIC ACID	142621	10	UG/L	6297C	1	SP-12	33.100	NC	SP13+14	10.000	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
HEXANOIC ACID	142621	10	UG/L	6297C	3	SP-12	456.000	NC	SP13+14	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297C	5	SP-12	239.500	NC	SP13+14	10.000	ND	390.639	10.000	97.44
HEXANOIC ACID	142621	10	UG/L	6297D	1	SP-4	10.000	ND						
HEXANOIC ACID	142621	10	UG/L	6297D	3	SP-4	10.000	ND						
HEXANOIC ACID	142621	10	UG/L	6297D	5	SP-4	10.000	ND				10.000		
HEXANOIC ACID	142621	10	UG/L	6297F	1				SP2+3	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297F	3				SP2+3	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297F	5				SP2+3	10.000	ND		10.000	
IRON	7439896	100	UG/L	6297C	1	SP-12	5590.000	NC	SP13+14	50.000	ND			
IRON	7439896	100	UG/L	6297C	2	SP-12	7210.000	NC	SP13+14	50.000	ND			
IRON	7439896	100	UG/L	6297C	3	SP-12	5580.000	NC	SP13+14	50.000	ND			
IRON	7439896	100	UG/L	6297C	4	SP-12	2230.000	NC	SP13+14	50.000	ND			
IRON	7439896	100	UG/L	6297C	5	SP-12	7150.000	NC	SP13+14	50.000	ND	5776.343	50.000	99.13
IRON	7439896	100	UG/L	6297D	1	SP-4	50.000	ND						
IRON	7439896	100	UG/L	6297D	2	SP-4	50.000	ND						
IRON	7439896	100	UG/L	6297D	3	SP-4	50.000	ND						
IRON	7439896	100	UG/L	6297D	4	SP-4	50.000	ND						
IRON	7439896	100	UG/L	6297D	5	SP-4	50.000	ND				50.000		
IRON	7439896	100	UG/L	6297F	1				SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297F	2				SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297F	3				SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297F	4				SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297F	5				SP2+3	50.000	ND		50.000	
MANGANESE	7439965	15	UG/L	6297C	1	SP-12	1350.000	NC	SP13+14	9.300	NC			
MANGANESE	7439965	15	UG/L	6297C	2	SP-12	882.000	NC	SP13+14	9.900	NC			
MANGANESE	7439965	15	UG/L	6297C	3	SP-12	1190.000	NC	SP13+14	8.650	NC			
MANGANESE	7439965	15	UG/L	6297C	4	SP-12	463.000	NC	SP13+14	8.700	NC			
MANGANESE	7439965	15	UG/L	6297C	5	SP-12	1740.000	NC	SP13+14	9.900	NC	1168.254	9.294	99.20
MANGANESE	7439965	15	UG/L	6297D	1	SP-4	5.000	ND						
MANGANESE	7439965	15	UG/L	6297D	2	SP-4	5.000	ND						
MANGANESE	7439965	15	UG/L	6297D	3	SP-4	5.000	ND						
MANGANESE	7439965	15	UG/L	6297D	4	SP-4	5.000	ND						
MANGANESE	7439965	15	UG/L	6297D	5	SP-4	5.000	ND				5.000		
MANGANESE	7439965	15	UG/L	6297F	1				SP2+3	5.000	ND			
MANGANESE	7439965	15	UG/L	6297F	2				SP2+3	5.000	ND			
MANGANESE	7439965	15	UG/L	6297F	3				SP2+3	5.000	ND			
MANGANESE	7439965	15	UG/L	6297F	4				SP2+3	5.000	ND			
MANGANESE	7439965	15	UG/L	6297F	5				SP2+3	5.000	ND		5.000	
NITRATE/NITRITE	C005	0.01	MG/L	6297C	1	SP-12	0.940	NC	SP13+14	0.250	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
NITRATE/NITRITE	C005	0.01	MG/L	6297C	2	SP-12	0.960	NC	SP13+14	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297C	3	SP-12	0.850	NC	SP13+14	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297C	4	SP-12	0.740	NC	SP13+14	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297C	5	SP-12	0.830	NC	SP13+14	0.250	ND	0.865	0.250	71.10
NITRATE/NITRITE	C005	0.01	MG/L	6297D	1	SP-4	1.080	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6297D	2	SP-4	1.040	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6297D	3	SP-4	1.080	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6297D	4	SP-4	1.120	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6297D	5	SP-4	1.080	NC				1.080		
NITRATE/NITRITE	C005	0.01	MG/L	6297F	1				SP2+3	1.040	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297F	2				SP2+3	0.970	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297F	3				SP2+3	0.940	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297F	4				SP2+3	1.110	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297F	5				SP2+3	1.050	NC		1.022	
SELENIUM	7782492	5	UG/L	6297C	1	SP-12	6.200	NC	SP13+14	2.000	ND			
SELENIUM	7782492	5	UG/L	6297C	2	SP-12	6.940	NC	SP13+14	2.000	ND			
SELENIUM	7782492	5	UG/L	6297C	3	SP-12	8.160	NC	SP13+14	2.000	ND			
SELENIUM	7782492	5	UG/L	6297C	4	SP-12	30.500	NC	SP13+14	2.000	ND			
SELENIUM	7782492	5	UG/L	6297C	5	SP-12	8.500	NC	SP13+14	2.000	ND	12.094	2.000	83.46
SELENIUM	7782492	5	UG/L	6297D	1	SP-4	2.000	ND						
SELENIUM	7782492	5	UG/L	6297D	2	SP-4	2.000	ND						
SELENIUM	7782492	5	UG/L	6297D	3	SP-4	2.000	ND						
SELENIUM	7782492	5	UG/L	6297D	4	SP-4	2.000	ND						
SELENIUM	7782492	5	UG/L	6297D	5	SP-4	2.000	ND				2.000		
SELENIUM	7782492	5	UG/L	6297F	1				SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297F	2				SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297F	3				SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297F	4				SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297F	5				SP2+3	2.000	ND		2.000	
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297C	1	SP-12	95.000	NC	SP13+14	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297C	2				SP13+14	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297C	3				SP13+14	1.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297C	4	SP-12	98.000	NC						
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297C	5				SP13+14	1.000	NC	96.500	0.550	99.43
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297C	1	SP-12	4.230	NC	SP13+14	5.000	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297C	2	SP-12	96.700	NC	SP13+14	133.000	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297C	3	SP-12	68.000	NC	SP13+14	4.105	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297C	4	SP-12	29.100	NC	SP13+14	4.225	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297C	5	SP-12	37.900	NC	SP13+14	4.930	NC	65.893	28.029	57.46
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297D	1	SP-4	0.500	ND						

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297D	2	SP-4	0.500	ND						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297D	3	SP-4	0.500	ND						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297D	4	SP-4	0.500	ND						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297D	5	SP-4	0.500	ND				0.500		
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297F	1				SP2+3	0.500	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297F	2				SP2+3	0.500	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297F	3				SP2+3	0.500	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297F	4				SP2+3	0.500	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297F	5				SP2+3	0.500	ND		0.500	
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297C	1	SP-12	18.400	NC	SP13+14	0.180	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297C	2	SP-12	4.300	NC	SP13+14	0.420	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297C	3	SP-12	24.600	NC	SP13+14	0.400	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297C	4	SP-12	8.210	NC	SP13+14	0.505	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297C	5	SP-12	17.500	NC	SP13+14	0.050	ND	15.841	0.322	97.97
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297D	1	SP-4	0.050	ND						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297D	2	SP-4	0.190	NC						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297D	3	SP-4	0.050	ND						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297D	4	SP-4	0.210	NC						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297D	5	SP-4	0.050	ND				0.110		
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297F	1				SP2+3	0.100	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297F	2				SP2+3	0.175	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297F	3				SP2+3	0.050	ND			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297F	4				SP2+3	0.210	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297F	5				SP2+3	0.090	NC		0.128	
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297C	1	SP-12	10.500	RC	SP13+14	0.560	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297C	2	SP-12	25.400	NC	SP13+14	0.780	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297C	3	SP-12	2.340	NC	SP13+14	0.635	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297C	4	SP-12	80.400	NC	SP13+14	0.390	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297C	5	SP-12	76.000	NC	SP13+14	0.780	NC	62.131	0.636	98.98
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297D	1	SP-4	0.250	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297D	2	SP-4	0.190	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297D	3	SP-4	0.079	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297D	4	SP-4	0.070	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297D	5	SP-4	0.094	NC				0.141		
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297F	1				SP2+3	0.050	ND			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297F	2				SP2+3	0.260	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297F	3				SP2+3	0.130	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297F	4				SP2+3	0.090	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297F	5				SP2+3	0.094	NC		0.127	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297C	1	SP-12	4050.000	NC	SP13+14	11.000	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297C	2	SP-12	707.000	NC	SP13+14	14.800	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297C	3	SP-12	2020.000	NC	SP13+14	9.800	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297C	4	SP-12	3360.000	NC	SP13+14	11.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297C	5	SP-12	2830.000	NC	SP13+14	8.400	NC	2829.903	11.166	99.61
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297D	1	SP-4	4.000	ND						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297D	2	SP-4	4.000	ND						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297D	3	SP-4	4.000	ND						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297D	4	SP-4	4.000	ND						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297D	5	SP-4	4.000	ND				4.000		
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297F	1				SP2+3	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297F	2				SP2+3	4.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297F	3				SP2+3	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297F	4				SP2+3	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297F	5				SP2+3	4.000	ND		4.100	
ZINC	7440666	20	UG/L	6297C	1	SP-12	3350.000	NC	SP13+14	15.400	NC			
ZINC	7440666	20	UG/L	6297C	2	SP-12	2190.000	NC	SP13+14	12.800	NC			
ZINC	7440666	20	UG/L	6297C	3	SP-12	3040.000	NC	SP13+14	12.250	NC			
ZINC	7440666	20	UG/L	6297C	4	SP-12	1180.000	NC	SP13+14	10.900	NC			
ZINC	7440666	20	UG/L	6297C	5	SP-12	3300.000	NC	SP13+14	13.000	NC	2691.931	12.889	99.52
ZINC	7440666	20	UG/L	6297D	1	SP-4	5.000	ND						
ZINC	7440666	20	UG/L	6297D	2	SP-4	5.000	ND						
ZINC	7440666	20	UG/L	6297D	3	SP-4	5.000	ND						
ZINC	7440666	20	UG/L	6297D	4	SP-4	5.000	ND						
ZINC	7440666	20	UG/L	6297D	5	SP-4	5.000	ND				5.000		
ZINC	7440666	20	UG/L	6297F	1				SP2+3	5.000	ND			
ZINC	7440666	20	UG/L	6297F	2				SP2+3	5.000	ND			
ZINC	7440666	20	UG/L	6297F	3				SP2+3	5.000	ND			
ZINC	7440666	20	UG/L	6297F	4				SP2+3	5.000	ND			
ZINC	7440666	20	UG/L	6297F	5				SP2+3	5.000	ND		5.000	

Subcategory=Flow-thru -- Option=OLSB

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
AEROMONAS	C2101	1	/100M	6460C	3	SP-8	100000.000	ND	SP-9	1000.000	ND	100000.000	1000.000	99.00
ALUMINUM	7429905	200	UG/L	6297A	1	SP-7	300.000	NC	SP8+9	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297A	2	SP-7	762.000	NC	SP8+9	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297A	3	SP-7	730.000	NC	SP8+9	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297A	4	SP-7	1090.000	NC	SP8+9	50.000	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=OLSB
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ALUMINUM	7429905	200	UG/L	6297A	5	SP-7	938.000	NC	SP8+9	54.200	NC	796.452	50.840	93.62
ALUMINUM	7429905	200	UG/L	6297B	1	SP-10	357.000	NC	SP-11	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297B	2	SP-10	683.000	NC	SP-11	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297B	3	SP-10	636.000	NC	SP-11	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297B	4	SP-10	486.000	NC	SP-11	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297B	5	SP-10	491.000	NC	SP-11	75.400	NC	534.549	55.080	89.70
ALUMINUM	7429905	200	UG/L	6460C	3	SP-8	2860.000	NC	SP-9	67.400	NC	2860.000	67.400	97.64
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297A	1	SP-7	2.850	NC	SP8+9	3.530	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297A	2	SP-7	0.950	NC	SP8+9	3.180	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297A	3	SP-7	1.190	NC	SP8+9	2.040	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297A	4	SP-7	0.900	NC	SP8+9	2.710	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297A	5	SP-7	1.420	NC	SP8+9	2.730	NC	1.478	2.852	-92.90
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297B	1	SP-10	0.370	NC	SP-11	0.400	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297B	2	SP-10	1.200	NC	SP-11	1.410	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297B	3	SP-10	1.460	NC	SP-11	0.910	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297B	4	SP-10	1.230	NC	SP-11	1.280	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297B	5	SP-10	0.740	NC	SP-11	1.680	NC	1.051	1.199	-14.08
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460C	3	SP-8	14.000	NC	SP-9	0.360	NC	14.000	0.360	97.43
BARIUM	7440393	200	UG/L	6297A	1	SP-7	66.900	NC	SP8+9	47.000	NC			
BARIUM	7440393	200	UG/L	6297A	2	SP-7	154.000	NC	SP8+9	43.500	NC			
BARIUM	7440393	200	UG/L	6297A	3	SP-7	140.000	NC	SP8+9	45.350	NC			
BARIUM	7440393	200	UG/L	6297A	4	SP-7	1060.000	NC	SP8+9	44.000	NC			
BARIUM	7440393	200	UG/L	6297A	5	SP-7	664.000	NC	SP8+9	45.200	NC	491.713	45.014	90.85
BARIUM	7440393	200	UG/L	6297B	1	SP-10	88.100	NC	SP-11	43.300	NC			
BARIUM	7440393	200	UG/L	6297B	2	SP-10	133.000	NC	SP-11	43.500	NC			
BARIUM	7440393	200	UG/L	6297B	3	SP-10	127.000	NC	SP-11	45.200	NC			
BARIUM	7440393	200	UG/L	6297B	4	SP-10	227.000	NC	SP-11	45.700	NC			
BARIUM	7440393	200	UG/L	6297B	5	SP-10	204.000	NC	SP-11	44.100	NC	158.369	44.362	71.99
BARIUM	7440393	200	UG/L	6460C	3	SP-8	565.000	NC	SP-9	20.700	NC	565.000	20.700	96.34
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297A	1	SP-7	366.000	RC	SP8+9	58.000	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297A	2	SP-7	186.000	RC	SP8+9	182.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297A	3	SP-7	380.000	RC	SP8+9	172.500	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297A	4	SP-7	3.780	NC	SP8+9	84.000	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297A	5	SP-7	179.000	NC	SP8+9	185.000	RC	716.288	142.072	80.17
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297B	1	SP-10	56.000	RC	SP-11	56.000	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297B	2	SP-10	178.000	RC	SP-11	70.000	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297B	3	SP-10	376.000	RC	SP-11	172.000	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297B	4	SP-10	93.000	RC	SP-11	85.000	RC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=OLSB
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297B	5	SP-10	163.000	NC	SP-11	183.000	RC	183.187	116.545	36.38
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460C	3	SP-8	3990.000	NC	SP-9	13.000	NC	3990.000	13.000	99.67
BORON	7440428	100	UG/L	6297A	1	SP-7	57.100	NC	SP8+9	51.000	NC			
BORON	7440428	100	UG/L	6297A	2	SP-7	68.300	NC	SP8+9	50.300	NC			
BORON	7440428	100	UG/L	6297A	3	SP-7	68.600	NC	SP8+9	50.850	NC			
BORON	7440428	100	UG/L	6297A	4	SP-7	955.000	NC	SP8+9	50.450	NC			
BORON	7440428	100	UG/L	6297A	5	SP-7	515.000	NC	SP8+9	51.600	NC	404.241	50.841	87.42
BORON	7440428	100	UG/L	6297B	1	SP-10	62.100	NC	SP-11	49.700	NC			
BORON	7440428	100	UG/L	6297B	2	SP-10	69.800	NC	SP-11	51.100	NC			
BORON	7440428	100	UG/L	6297B	3	SP-10	69.200	NC	SP-11	49.700	NC			
BORON	7440428	100	UG/L	6297B	4	SP-10	229.000	NC	SP-11	50.600	NC			
BORON	7440428	100	UG/L	6297B	5	SP-10	189.000	NC	SP-11	50.200	NC	128.202	50.261	60.80
BORON	7440428	100	UG/L	6460C	3	SP-8	119.000	NC	SP-9	2.000	ND	119.000	2.000	98.32
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297A	1	SP-7	2020.000	NC	SP8+9	642.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297A	2	SP-7	2060.000	NC	SP8+9	398.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297A	3	SP-7	1880.000	NC	SP8+9	372.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297A	4	SP-7	105.000	RC	SP8+9	412.500	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297A	5	SP-7	487.000	RC	SP8+9	380.000	NC	1958.783	442.324	77.42
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297B	1	SP-10	1730.000	NC	SP-11	367.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297B	2	SP-10	1760.000	NC	SP-11	442.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297B	3	SP-10	2230.000	NC	SP-11	397.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297B	4	SP-10	1190.000	RC	SP-11	472.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297B	5	SP-10	180.000	RC	SP-11	360.000	NC	1823.326	408.144	77.62
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460C	3	SP-8	9100.000	NC	SP-9	33.000	NC	9100.000	33.000	99.64
COPPER	7440508	25	UG/L	6297A	1	SP-7	68.000	NC	SP8+9	14.500	NC			
COPPER	7440508	25	UG/L	6297A	2	SP-7	132.000	NC	SP8+9	12.200	NC			
COPPER	7440508	25	UG/L	6297A	3	SP-7	131.000	NC	SP8+9	12.500	NC			
COPPER	7440508	25	UG/L	6297A	4	SP-7	112.000	NC	SP8+9	11.250	NC			
COPPER	7440508	25	UG/L	6297A	5	SP-7	139.000	NC	SP8+9	12.400	NC	117.855	12.580	89.33
COPPER	7440508	25	UG/L	6297B	1	SP-10	93.400	NC	SP-11	9.400	NC			
COPPER	7440508	25	UG/L	6297B	2	SP-10	141.000	NC	SP-11	13.600	NC			
COPPER	7440508	25	UG/L	6297B	3	SP-10	141.000	NC	SP-11	15.900	NC			
COPPER	7440508	25	UG/L	6297B	4	SP-10	86.700	NC	SP-11	14.300	NC			
COPPER	7440508	25	UG/L	6297B	5	SP-10	83.500	NC	SP-11	13.800	NC	109.822	13.468	87.74
COPPER	7440508	25	UG/L	6460C	3	SP-8	192.000	NC	SP-9	1.000	ND	192.000	1.000	99.48
FECAL STREPTOCOCCUS	C2107	1	/100M	6460C	3	SP-8	2900000.00	NC	SP-9	2500.000	NC	2900000.00	2500.000	99.91

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=OLSB
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297A	1	SP-7	46.700	NC	SP8+9	5.000	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297A	2	SP-7	64.500	NC	SP8+9	10.900	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297A	3	SP-7	72.667	NC	SP8+9	68.667	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297A	4	SP-7	20.497	NC	SP8+9	85.350	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297A	5	SP-7	200.893	NC	SP8+9	76.033	NC	86.761	70.879	18.31
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297B	1	SP-10	5.000	ND	SP-11	9.933	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297B	2	SP-10	84.467	NC	SP-11	12.800	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297B	3	SP-10	186.267	NC	SP-11	105.667	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297B	4	SP-10	93.333	NC	SP-11	109.500	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297B	5	SP-10	30.633	NC	SP-11	76.700	NC	87.403	82.319	5.82
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460C	3	SP-8	735.000	NC	SP-9	6.000	ND	735.000	6.000	99.18
HEXANOIC ACID	142621	10	UG/L	6297A	1	SP-7	109.000	NC	SP8+9	115.000	NC			
HEXANOIC ACID	142621	10	UG/L	6297A	3	SP-7	52.800	NC	SP8+9	110.850	NC			
HEXANOIC ACID	142621	10	UG/L	6297A	5	SP-7	47.600	NC	SP8+9	111.000	NC	71.912	112.291	-56.15
HEXANOIC ACID	142621	10	UG/L	6297B	1	SP-10	38.100	NC	SP-11	85.400	NC			
HEXANOIC ACID	142621	10	UG/L	6297B	3	SP-10	75.800	NC	SP-11	103.000	NC			
HEXANOIC ACID	142621	10	UG/L	6297B	5	SP-10	24.400	NC	SP-11	142.000	NC	48.619	111.315	-128.95
HEXANOIC ACID	142621	10	UG/L	6460C	3	SP-8	965.000	NC	SP-9	10.000	ND	965.000	10.000	98.96
IRON	7439896	100	UG/L	6297A	1	SP-7	885.000	NC	SP8+9	231.000	NC			
IRON	7439896	100	UG/L	6297A	2	SP-7	2440.000	NC	SP8+9	230.000	NC			
IRON	7439896	100	UG/L	6297A	3	SP-7	2260.000	NC	SP8+9	229.000	NC			
IRON	7439896	100	UG/L	6297A	4	SP-7	1500.000	NC	SP8+9	210.000	NC			
IRON	7439896	100	UG/L	6297A	5	SP-7	2930.000	NC	SP8+9	218.000	NC	2070.117	223.641	89.20
IRON	7439896	100	UG/L	6297B	1	SP-10	1390.000	NC	SP-11	264.000	NC			
IRON	7439896	100	UG/L	6297B	2	SP-10	2230.000	NC	SP-11	280.000	NC			
IRON	7439896	100	UG/L	6297B	3	SP-10	1890.000	NC	SP-11	269.000	NC			
IRON	7439896	100	UG/L	6297B	4	SP-10	1270.000	NC	SP-11	257.000	NC			
IRON	7439896	100	UG/L	6297B	5	SP-10	1260.000	NC	SP-11	283.000	NC	1617.388	270.644	83.27
IRON	7439896	100	UG/L	6460C	3	SP-8	32200.000	NC	SP-9	559.000	NC	32200.000	559.000	98.26
MANGANESE	7439965	15	UG/L	6297A	1	SP-7	166.000	NC	SP8+9	162.000	NC			
MANGANESE	7439965	15	UG/L	6297A	2	SP-7	593.000	NC	SP8+9	143.000	NC			
MANGANESE	7439965	15	UG/L	6297A	3	SP-7	463.000	NC	SP8+9	146.000	NC			
MANGANESE	7439965	15	UG/L	6297A	4	SP-7	286.000	NC	SP8+9	141.500	NC			
MANGANESE	7439965	15	UG/L	6297A	5	SP-7	551.000	NC	SP8+9	141.000	NC	429.666	146.745	65.85
MANGANESE	7439965	15	UG/L	6297B	1	SP-10	352.000	NC	SP-11	170.000	NC			
MANGANESE	7439965	15	UG/L	6297B	2	SP-10	642.000	NC	SP-11	180.000	NC			
MANGANESE	7439965	15	UG/L	6297B	3	SP-10	575.000	NC	SP-11	195.000	NC			
MANGANESE	7439965	15	UG/L	6297B	4	SP-10	330.000	NC	SP-11	190.000	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=OLSB
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
MANGANESE	7439965	15	UG/L	6297B	5	SP-10	280.000	NC	SP-11	179.000	NC	441.278	182.853	58.56
MANGANESE	7439965	15	UG/L	6460C	3	SP-8	3990.000	NC	SP-9	41.100	NC	3990.000	41.100	98.97
NITRATE/NITRITE	C005	0.01	MG/L	6297A	1	SP-7	0.750	NC	SP8+9	0.500	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297A	2	SP-7	1.260	NC	SP8+9	0.500	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297A	3	SP-7	0.720	NC	SP8+9	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297A	4	SP-7	0.870	NC	SP8+9	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297A	5	SP-7	0.740	NC	SP8+9	0.250	ND	0.871	0.350	59.83
NITRATE/NITRITE	C005	0.01	MG/L	6297B	1	SP-10	0.720	NC	SP-11	0.500	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297B	2	SP-10	0.740	NC	SP-11	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297B	3	SP-10	1.090	NC	SP-11	1.940	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297B	4	SP-10	0.770	NC	SP-11	0.250	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297B	5	SP-10	0.780	NC	SP-11	0.250	ND	0.822	0.638	22.36
NITRATE/NITRITE	C005	0.01	MG/L	6460C	3	SP-8	0.550	NC	SP-9	0.090	NC	0.550	0.090	83.64
SELENIUM	7782492	5	UG/L	6297A	1	SP-7	2.500	NC	SP8+9	2.000	ND			
SELENIUM	7782492	5	UG/L	6297A	2	SP-7	2.000	ND	SP8+9	2.000	ND			
SELENIUM	7782492	5	UG/L	6297A	3	SP-7	4.600	NC	SP8+9	2.000	ND			
SELENIUM	7782492	5	UG/L	6297A	4	SP-7	3.720	NC	SP8+9	2.000	ND			
SELENIUM	7782492	5	UG/L	6297A	5	SP-7	4.520	NC	SP8+9	2.000	ND	3.505	2.000	42.95
SELENIUM	7782492	5	UG/L	6297B	1	SP-10	2.100	NC	SP-11	2.000	ND			
SELENIUM	7782492	5	UG/L	6297B	2	SP-10	2.000	ND	SP-11	2.000	ND			
SELENIUM	7782492	5	UG/L	6297B	3	SP-10	3.200	NC	SP-11	4.000	NC			
SELENIUM	7782492	5	UG/L	6297B	4	SP-10	2.000	ND	SP-11	2.000	ND			
SELENIUM	7782492	5	UG/L	6297B	5	SP-10	2.000	ND	SP-11	2.000	ND	2.284	2.400	-5.08
SELENIUM	7782492	5	UG/L	6460C	3	SP-8	11.000	NC	SP-9	2.000	ND	11.000	2.000	81.82
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297A	1	SP-7	70.000	NC	SP8+9	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297A	2				SP8+9	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297A	3	SP-7	50.000	NC	SP8+9	1.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297A	4	SP-7	59.000	NC	SP8+9	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297A	5	SP-7	105.000	NC	SP8+9	0.100	ND	71.788	0.280	99.61
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297B	1	SP-10	21.000	NC	SP-11	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297B	2				SP-11	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297B	3	SP-10	69.000	NC	SP-11	1.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297B	4	SP-10	41.000	NC	SP-11	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297B	5	SP-10	31.000	NC	SP-11	2.000	NC	41.750	0.698	98.33
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6460C	3	SP-8	240.000	NC	SP-9	0.200	NC	240.000	0.200	99.92
TOTAL COLIFORM	E10606	1	/100M	6460C	3	SP-8	10900.000	NC	SP-9	460.000	NC	10900.000	460.000	95.78

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=OLSB
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297A	1	SP-7	69.100	NC	SP8+9	14.900	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297A	2	SP-7	57.500	NC	SP8+9	13.100	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297A	3	SP-7	142.000	NC	SP8+9	13.100	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297A	4	SP-7	12.500	NC	SP8+9	13.750	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297A	5	SP-7	34.300	NC	SP8+9	14.000	NC	71.441	13.774	80.72
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297B	1	SP-10	37.300	NC	SP-11	0.700	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297B	2	SP-10	67.500	NC	SP-11	13.900	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297B	3	SP-10	98.600	NC	SP-11	14.000	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297B	4	SP-10	14.300	NC	SP-11	13.300	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297B	5	SP-10	13.200	NC	SP-11	13.500	NC	51.405	18.255	64.49
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460C	3	SP-8	68.400	NC	SP-9	1.900	NC	68.400	1.900	97.22
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297A	1	SP-7	6.380	NC	SP8+9	12.100	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297A	2	SP-7	17.300	NC	SP8+9	11.000	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297A	3	SP-7	8.480	NC	SP8+9	10.145	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297A	4	SP-7	9.120	NC	SP8+9	10.850	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297A	5	SP-7	8.010	NC	SP8+9	11.100	NC	9.938	11.043	-11.12
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297B	1	SP-10	7.280	NC	SP-11	9.680	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297B	2	SP-10	10.100	NC	SP-11	11.500	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297B	3	SP-10	11.000	NC	SP-11	11.500	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297B	4	SP-10	4.690	NC	SP-11	10.700	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297B	5	SP-10	3.150	NC	SP-11	10.300	NC	7.516	10.742	-42.92
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460C	3	SP-8	33.300	NC	SP-9	0.370	NC	33.300	0.370	98.89
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297A	1	SP-7	10.500	RC	SP8+9	10.500	RC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297A	2	SP-7	41.300	NC	SP8+9	10.900	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297A	3	SP-7	41.800	NC	SP8+9	10.075	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297A	4	SP-7	17.900	NC	SP8+9	9.670	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297A	5	SP-7	19.500	NC	SP8+9	9.670	NC	27.320	10.166	62.79
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297B	1	SP-10	10.500	RC	SP-11	8.630	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297B	2	SP-10	22.900	NC	SP-11	11.100	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297B	3	SP-10	0.200	NC	SP-11	10.800	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297B	4	SP-10	16.700	NC	SP-11	8.530	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297B	5	SP-10	10.100	NC	SP-11	8.320	NC	39.427	9.494	75.92
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460C	3	SP-8	61.100	NC	SP-9	0.360	NC	61.100	0.360	99.41
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297A	1	SP-7	1000.000	NC	SP8+9	70.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297A	2	SP-7	553.000	NC	SP8+9	44.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297A	3	SP-7	1040.000	NC	SP8+9	46.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297A	4	SP-7	1710.000	NC	SP8+9	69.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297A	5	SP-7	363.000	NC	SP8+9	60.000	NC	976.155	58.104	94.05

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=OLSB (continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297B	1	SP-10	1040.000	NC	SP-11	56.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297B	2	SP-10	687.000	NC	SP-11	68.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297B	3	SP-10	4.000	ND	SP-11	74.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297B	4	SP-10	540.000	NC	SP-11	72.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297B	5	SP-10	690.000	NC	SP-11	78.000	NC	597.100	69.731	88.32
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460C	3	SP-8	11800.000	NC	SP-9	38.000	NC	11800.000	38.000	99.68
ZINC	7440666	20	UG/L	6297A	1	SP-7	386.000	NC	SP8+9	75.800	NC			
ZINC	7440666	20	UG/L	6297A	2	SP-7	1060.000	NC	SP8+9	63.000	NC			
ZINC	7440666	20	UG/L	6297A	3	SP-7	952.000	NC	SP8+9	69.950	NC			
ZINC	7440666	20	UG/L	6297A	4	SP-7	1600.000	NC	SP8+9	69.900	NC			
ZINC	7440666	20	UG/L	6297A	5	SP-7	1640.000	NC	SP8+9	74.500	NC	1193.105	70.669	94.08
ZINC	7440666	20	UG/L	6297B	1	SP-10	768.000	NC	SP-11	61.800	NC			
ZINC	7440666	20	UG/L	6297B	2	SP-10	1170.000	NC	SP-11	98.700	NC			
ZINC	7440666	20	UG/L	6297B	3	SP-10	1070.000	NC	SP-11	116.000	NC			
ZINC	7440666	20	UG/L	6297B	4	SP-10	792.000	NC	SP-11	106.000	NC			
ZINC	7440666	20	UG/L	6297B	5	SP-10	625.000	NC	SP-11	94.900	NC	890.912	96.233	89.20
ZINC	7440666	20	UG/L	6460C	3	SP-8	3770.000	NC	SP-9	30.200	NC	3770.000	30.200	99.20

Subcategory=Flow-thru -- Option=Raceway

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ALUMINUM	7429905	200	UG/L	6297E	1				SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297E	2				SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297E	3				SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297E	4				SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297E	5				SP5+6	50.000	ND		50.000	
ALUMINUM	7429905	200	UG/L	6460B	1				SP-7	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460B	2				SP-7	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460B	3				SP-7	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460B	4				SP-7	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460B	5				SP-7	48.000	ND		48.000	
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297E	1				SP5+6	0.370	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297E	2				SP5+6	0.840	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297E	3				SP5+6	0.340	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297E	4				SP5+6	0.380	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297E	5				SP5+6	0.370	NC		0.462	
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460B	1				SP-7	0.220	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=Raceway
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460B	2				SP-7	0.100	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460B	3				SP-7	0.120	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460B	4				SP-7	0.160	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460B	5				SP-7	0.120	NC		0.145	
BARIUM	7440393	200	UG/L	6297E	1				SP5+6	22.000	NC			
BARIUM	7440393	200	UG/L	6297E	2				SP5+6	21.600	NC			
BARIUM	7440393	200	UG/L	6297E	3				SP5+6	22.000	NC			
BARIUM	7440393	200	UG/L	6297E	4				SP5+6	21.500	NC			
BARIUM	7440393	200	UG/L	6297E	5				SP5+6	21.800	NC		21.780	
BARIUM	7440393	200	UG/L	6460B	1				SP-7	22.200	NC			
BARIUM	7440393	200	UG/L	6460B	2				SP-7	22.000	NC			
BARIUM	7440393	200	UG/L	6460B	3				SP-7	17.900	NC			
BARIUM	7440393	200	UG/L	6460B	4				SP-7	17.100	NC			
BARIUM	7440393	200	UG/L	6460B	5				SP-7	18.000	NC		19.469	
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297E	1				SP5+6	3.250	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297E	2				SP5+6	4.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297E	3				SP5+6	4.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297E	4				SP5+6	6.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297E	5				SP5+6	4.200	NC		4.302	
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460B	1				SP-7	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460B	2				SP-7	6.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460B	3				SP-7	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460B	4				SP-7	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460B	5				SP-7	2.000	ND		2.800	
BORON	7440428	100	UG/L	6297E	1				SP5+6	47.750	NC			
BORON	7440428	100	UG/L	6297E	2				SP5+6	46.850	NC			
BORON	7440428	100	UG/L	6297E	3				SP5+6	44.900	NC			
BORON	7440428	100	UG/L	6297E	4				SP5+6	47.200	NC			
BORON	7440428	100	UG/L	6297E	5				SP5+6	46.000	NC		46.543	
BORON	7440428	100	UG/L	6460B	1				SP-7	30.900	NC			
BORON	7440428	100	UG/L	6460B	2				SP-7	378.000	NC			
BORON	7440428	100	UG/L	6460B	3				SP-7	2.000	ND			
BORON	7440428	100	UG/L	6460B	4				SP-7	2.000	ND			
BORON	7440428	100	UG/L	6460B	5				SP-7	2.000	ND		208.509	
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297E	1				SP5+6	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297E	2				SP5+6	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297E	3				SP5+6	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297E	4				SP5+6	20.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297E	5				SP5+6	20.000	ND		20.000	
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460B	1				SP-7	14.000	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=Raceway (continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460B	2				SP-7	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460B	3				SP-7	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460B	4				SP-7	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460B	5				SP-7	10.000	ND		10.800	
COPPER	7440508	25	UG/L	6297E	1				SP5+6	5.000	ND			
COPPER	7440508	25	UG/L	6297E	2				SP5+6	5.000	ND			
COPPER	7440508	25	UG/L	6297E	3				SP5+6	5.000	ND			
COPPER	7440508	25	UG/L	6297E	4				SP5+6	5.000	ND			
COPPER	7440508	25	UG/L	6297E	5				SP5+6	5.000	ND		5.000	
COPPER	7440508	25	UG/L	6460B	1				SP-7	1.000	ND			
COPPER	7440508	25	UG/L	6460B	2				SP-7	1.000	ND			
COPPER	7440508	25	UG/L	6460B	3				SP-7	1.000	ND			
COPPER	7440508	25	UG/L	6460B	4				SP-7	1.000	ND			
COPPER	7440508	25	UG/L	6460B	5				SP-7	1.000	ND		1.000	
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297E	1				SP5+6	5.093	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297E	2				SP5+6	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297E	3				SP5+6	6.020	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297E	4				SP5+6	23.967	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297E	5				SP5+6	8.197	NC		10.272	
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460B	1				SP-7	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460B	2				SP-7	5.500	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460B	3				SP-7	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460B	4				SP-7	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460B	5				SP-7	6.000	ND		5.900	
HEXANOIC ACID	142621	10	UG/L	6297E	1				SP5+6	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297E	3				SP5+6	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297E	5				SP5+6	10.000	ND		10.000	
HEXANOIC ACID	142621	10	UG/L	6460B	1				SP-7	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6460B	3				SP-7	10.000	ND		10.000	
IRON	7439896	100	UG/L	6297E	1				SP5+6	50.000	ND			
IRON	7439896	100	UG/L	6297E	2				SP5+6	50.000	ND			
IRON	7439896	100	UG/L	6297E	3				SP5+6	50.000	ND			
IRON	7439896	100	UG/L	6297E	4				SP5+6	50.000	ND			
IRON	7439896	100	UG/L	6297E	5				SP5+6	50.000	ND		50.000	
IRON	7439896	100	UG/L	6460B	1				SP-7	87.100	NC			
IRON	7439896	100	UG/L	6460B	2				SP-7	92.900	NC			
IRON	7439896	100	UG/L	6460B	3				SP-7	20.000	ND			
IRON	7439896	100	UG/L	6460B	4				SP-7	27.500	NC			
IRON	7439896	100	UG/L	6460B	5				SP-7	25.600	NC		54.144	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=Raceway
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
MANGANESE	7439965	15	UG/L	6297E	1				SP5+6	5.000	ND			
MANGANESE	7439965	15	UG/L	6297E	2				SP5+6	5.000	ND			
MANGANESE	7439965	15	UG/L	6297E	3				SP5+6	5.000	ND			
MANGANESE	7439965	15	UG/L	6297E	4				SP5+6	5.000	ND			
MANGANESE	7439965	15	UG/L	6297E	5				SP5+6	5.000	ND		5.000	
MANGANESE	7439965	15	UG/L	6460B	1				SP-7	18.500	NC			
MANGANESE	7439965	15	UG/L	6460B	2				SP-7	18.200	NC			
MANGANESE	7439965	15	UG/L	6460B	3				SP-7	5.500	NC			
MANGANESE	7439965	15	UG/L	6460B	4				SP-7	7.600	NC			
MANGANESE	7439965	15	UG/L	6460B	5				SP-7	6.000	NC		11.552	
NITRATE/NITRITE	C005	0.01	MG/L	6297E	1				SP5+6	1.050	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297E	2				SP5+6	1.000	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297E	3				SP5+6	0.970	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297E	4				SP5+6	1.040	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297E	5				SP5+6	1.090	NC		1.030	
NITRATE/NITRITE	C005	0.01	MG/L	6460B	1				SP-7	0.140	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460B	2				SP-7	0.160	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460B	3				SP-7	0.240	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460B	4				SP-7	0.750	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460B	5				SP-7	0.670	NC		0.419	
SELENIUM	7782492	5	UG/L	6297E	1				SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297E	2				SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297E	3				SP5+6	2.400	NC			
SELENIUM	7782492	5	UG/L	6297E	4				SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297E	5				SP5+6	2.000	ND		2.080	
SELENIUM	7782492	5	UG/L	6460B	1				SP-7	2.000	ND			
SELENIUM	7782492	5	UG/L	6460B	2				SP-7	2.000	ND			
SELENIUM	7782492	5	UG/L	6460B	3				SP-7	2.000	ND			
SELENIUM	7782492	5	UG/L	6460B	4				SP-7	2.000	ND			
SELENIUM	7782492	5	UG/L	6460B	5				SP-7	2.000	ND		2.000	
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297E	1				SP5+6	0.665	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297E	2				SP5+6	6.670	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297E	3				SP5+6	0.680	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297E	4				SP5+6	0.640	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297E	5				SP5+6	0.600	NC		1.779	
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460B	1				SP-7	0.330	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460B	2				SP-7	0.250	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460B	3				SP-7	0.230	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460B	4				SP-7	0.220	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460B	5				SP-7	0.310	NC		0.269	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=Raceway
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297E	1				SP5+6	0.179	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297E	2				SP5+6	0.155	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297E	3				SP5+6	0.083	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297E	4				SP5+6	0.320	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297E	5				SP5+6	0.130	NC		0.177	
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460B	1				SP-7	0.030	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460B	2				SP-7	0.030	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460B	3				SP-7	0.010	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460B	4				SP-7	0.020	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460B	5				SP-7	0.010	NC		0.021	
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297E	1				SP5+6	0.180	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297E	2				SP5+6	0.235	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297E	3				SP5+6	0.240	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297E	4				SP5+6	0.050	ND			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297E	5				SP5+6	0.150	NC		0.172	
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460B	1				SP-7	0.060	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460B	2				SP-7	0.060	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460B	3				SP-7	0.040	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460B	4				SP-7	0.030	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460B	5				SP-7	0.030	NC		0.045	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297E	1				SP5+6	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297E	2				SP5+6	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297E	3				SP5+6	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297E	4				SP5+6	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297E	5				SP5+6	4.000	ND		4.000	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460B	1				SP-7	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460B	2				SP-7	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460B	3				SP-7	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460B	4				SP-7	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460B	5				SP-7	4.000	ND		4.000	
ZINC	7440666	20	UG/L	6297E	1				SP5+6	5.900	NC			
ZINC	7440666	20	UG/L	6297E	2				SP5+6	5.000	ND			
ZINC	7440666	20	UG/L	6297E	3				SP5+6	5.000	ND			
ZINC	7440666	20	UG/L	6297E	4				SP5+6	5.000	ND			
ZINC	7440666	20	UG/L	6297E	5				SP5+6	5.000	ND		5.180	
ZINC	7440666	20	UG/L	6460B	1				SP-7	1.800	NC			
ZINC	7440666	20	UG/L	6460B	2				SP-7	1.100	NC			
ZINC	7440666	20	UG/L	6460B	3				SP-7	1.000	ND			
ZINC	7440666	20	UG/L	6460B	4				SP-7	1.900	NC			
ZINC	7440666	20	UG/L	6460B	5				SP-7	2.000	NC		1.576	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
AEROMONAS	C2101	1	/100M	6460A	3				SP7,SP9	1000.000	ND		1000.000	
ALUMINUM	7429905	200	UG/L	6297G	1	SP-7	300.000	NC	SP8+9,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297G	2	SP-7	762.000	NC	SP8+9,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297G	3	SP-7	730.000	NC	SP8+9,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297G	4	SP-7	1090.000	NC	SP8+9,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297G	5	SP-7	938.000	NC	SP8+9,SP5+6	50.042	NC	796.452	50.008	93.72
ALUMINUM	7429905	200	UG/L	6297H	1	SP-10	357.000	NC	SP11,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297H	2	SP-10	683.000	NC	SP11,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297H	3	SP-10	636.000	NC	SP11,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297H	4	SP-10	486.000	NC	SP11,SP5+6	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297H	5	SP-10	491.000	NC	SP11,SP5+6	50.251	ND	534.549	50.050	90.64
ALUMINUM	7429905	200	UG/L	6297I	1	SP-12	1940.000	NC	SP13+14,SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297I	2	SP-12	2210.000	NC	SP13+14,SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297I	3	SP-12	2950.000	NC	SP13+14,SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297I	4	SP-12	720.000	NC	SP13+14,SP2+3	50.000	ND			
ALUMINUM	7429905	200	UG/L	6297I	5	SP-12	2610.000	NC	SP13+14,SP2+3	50.000	ND	2205.664	50.000	97.73
ALUMINUM	7429905	200	UG/L	6460A	1				SP7,SP9	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460A	2				SP7,SP9	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460A	3				SP7,SP9	63.794	NC			
ALUMINUM	7429905	200	UG/L	6460A	4				SP7,SP9	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460A	5				SP7,SP9	48.000	ND		51.159	
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297G	1	SP-7	2.850	NC	SP8+9,SP5+6	0.401	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297G	2	SP-7	0.950	NC	SP8+9,SP5+6	0.863	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297G	3	SP-7	1.190	NC	SP8+9,SP5+6	0.357	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297G	4	SP-7	0.900	NC	SP8+9,SP5+6	0.403	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297G	5	SP-7	1.420	NC	SP8+9,SP5+6	0.393	NC	1.478	0.486	67.12
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297H	1	SP-10	0.370	NC	SP11,SP5+6	0.370	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297H	2	SP-10	1.200	NC	SP11,SP5+6	0.846	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297H	3	SP-10	1.460	NC	SP11,SP5+6	0.346	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297H	4	SP-10	1.230	NC	SP11,SP5+6	0.389	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297H	5	SP-10	0.740	NC	SP11,SP5+6	0.383	NC	1.051	0.469	55.37
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297I	1	SP-12	1.160	NC	SP13+14,SP2+3	0.155	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297I	2	SP-12	1.940	NC	SP13+14,SP2+3	0.127	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297I	3	SP-12	4.200	NC	SP13+14,SP2+3	0.129	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297I	4	SP-12	1.520	NC	SP13+14,SP2+3	0.112	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6297I	5	SP-12	1.440	NC	SP13+14,SP2+3	0.110	NC	2.075	0.127	93.88
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460A	1				SP7,SP9	0.220	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460A	2				SP7,SP9	0.100	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460A	3				SP7,SP9	0.315	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460A	4				SP7,SP9	0.160	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460A	5				SP7,SP9	0.120	NC		0.187	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BARIUM	7440393	200	UG/L	6297G	1	SP-7	66.900	NC	SP8+9,SP5+6	22.248	NC			
BARIUM	7440393	200	UG/L	6297G	2	SP-7	154.000	NC	SP8+9,SP5+6	21.817	NC			
BARIUM	7440393	200	UG/L	6297G	3	SP-7	140.000	NC	SP8+9,SP5+6	22.231	NC			
BARIUM	7440393	200	UG/L	6297G	4	SP-7	1060.000	NC	SP8+9,SP5+6	21.723	NC			
BARIUM	7440393	200	UG/L	6297G	5	SP-7	664.000	NC	SP8+9,SP5+6	22.032	NC	491.713	22.010	95.52
BARIUM	7440393	200	UG/L	6297H	1	SP-10	88.100	NC	SP11,SP5+6	22.210	NC			
BARIUM	7440393	200	UG/L	6297H	2	SP-10	133.000	NC	SP11,SP5+6	21.816	NC			
BARIUM	7440393	200	UG/L	6297H	3	SP-10	127.000	NC	SP11,SP5+6	22.229	NC			
BARIUM	7440393	200	UG/L	6297H	4	SP-10	227.000	NC	SP11,SP5+6	21.739	NC			
BARIUM	7440393	200	UG/L	6297H	5	SP-10	204.000	NC	SP11,SP5+6	22.020	NC	158.369	22.003	86.11
BARIUM	7440393	200	UG/L	6297I	1	SP-12	317.000	NC	SP13+14,SP2+3	22.653	NC			
BARIUM	7440393	200	UG/L	6297I	2	SP-12	288.000	NC	SP13+14,SP2+3	21.659	NC			
BARIUM	7440393	200	UG/L	6297I	3	SP-12	327.000	NC	SP13+14,SP2+3	21.811	NC			
BARIUM	7440393	200	UG/L	6297I	4	SP-12	249.000	NC	SP13+14,SP2+3	21.516	NC			
BARIUM	7440393	200	UG/L	6297I	5	SP-12	382.000	NC	SP13+14,SP2+3	21.520	NC	313.402	21.833	93.03
BARIUM	7440393	200	UG/L	6460A	1				SP7,SP9	22.200	NC			
BARIUM	7440393	200	UG/L	6460A	2				SP7,SP9	22.000	NC			
BARIUM	7440393	200	UG/L	6460A	3				SP7,SP9	20.180	NC			
BARIUM	7440393	200	UG/L	6460A	4				SP7,SP9	17.100	NC			
BARIUM	7440393	200	UG/L	6460A	5				SP7,SP9	18.000	NC		19.924	
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297G	1	SP-7	366.000	RC	SP8+9,SP5+6	3.792	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297G	2	SP-7	186.000	RC	SP8+9,SP5+6	5.762	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297G	3	SP-7	380.000	RC	SP8+9,SP5+6	5.668	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297G	4	SP-7	3.780	NC	SP8+9,SP5+6	6.772	RC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297G	5	SP-7	179.000	NC	SP8+9,SP5+6	5.990	RC	716.288	5.632	99.21
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297H	1	SP-10	56.000	RC	SP11,SP5+6	3.771	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297H	2	SP-10	178.000	RC	SP11,SP5+6	4.652	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297H	3	SP-10	376.000	RC	SP11,SP5+6	5.659	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297H	4	SP-10	93.000	RC	SP11,SP5+6	6.780	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297H	5	SP-10	163.000	NC	SP11,SP5+6	5.965	NC	183.187	5.418	97.04
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297I	1	SP-12	369.000	RC	SP13+14,SP2+3	3.175	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297I	2	SP-12	377.000	RC	SP13+14,SP2+3	4.467	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297I	3	SP-12	380.000	RC	SP13+14,SP2+3	4.101	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297I	4	SP-12	184.000	RC	SP13+14,SP2+3	6.105	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6297I	5	SP-12	380.000	RC	SP13+14,SP2+3	2.325	NC	343.432	4.048	98.82
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460A	1				SP7,SP9	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460A	2				SP7,SP9	6.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460A	3				SP7,SP9	10.955	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460A	4				SP7,SP9	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460A	5				SP7,SP9	2.000	ND		4.591	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BORON	7440428	100	UG/L	6297G	1	SP-7	57.100	NC	SP8+9,SP5+6	47.782	NC			
BORON	7440428	100	UG/L	6297G	2	SP-7	68.300	NC	SP8+9,SP5+6	46.884	NC			
BORON	7440428	100	UG/L	6297G	3	SP-7	68.600	NC	SP8+9,SP5+6	44.959	NC			
BORON	7440428	100	UG/L	6297G	4	SP-7	955.000	NC	SP8+9,SP5+6	47.232	NC			
BORON	7440428	100	UG/L	6297G	5	SP-7	515.000	NC	SP8+9,SP5+6	46.055	NC	404.241	46.585	88.48
BORON	7440428	100	UG/L	6297H	1	SP-10	62.100	NC	SP11,SP5+6	47.769	NC			
BORON	7440428	100	UG/L	6297H	2	SP-10	69.800	NC	SP11,SP5+6	46.892	NC			
BORON	7440428	100	UG/L	6297H	3	SP-10	69.200	NC	SP11,SP5+6	44.947	NC			
BORON	7440428	100	UG/L	6297H	4	SP-10	229.000	NC	SP11,SP5+6	47.234	NC			
BORON	7440428	100	UG/L	6297H	5	SP-10	189.000	NC	SP11,SP5+6	46.041	NC	128.202	46.579	63.67
BORON	7440428	100	UG/L	6297I	1	SP-12	105.000	NC	SP13+14,SP2+3	50.970	NC			
BORON	7440428	100	UG/L	6297I	2	SP-12	226.000	NC	SP13+14,SP2+3	50.016	NC			
BORON	7440428	100	UG/L	6297I	3	SP-12	216.000	NC	SP13+14,SP2+3	48.009	NC			
BORON	7440428	100	UG/L	6297I	4	SP-12	231.000	NC	SP13+14,SP2+3	48.878	NC			
BORON	7440428	100	UG/L	6297I	5	SP-12	136.000	NC	SP13+14,SP2+3	45.045	NC	185.838	48.595	73.85
BORON	7440428	100	UG/L	6460A	1				SP7,SP9	30.900	NC			
BORON	7440428	100	UG/L	6460A	2				SP7,SP9	378.000	NC			
BORON	7440428	100	UG/L	6460A	3				SP7,SP9	2.000	ND			
BORON	7440428	100	UG/L	6460A	4				SP7,SP9	2.000	ND			
BORON	7440428	100	UG/L	6460A	5				SP7,SP9	2.000	ND		208.509	
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297G	1	SP-7	2020.000	NC	SP8+9,SP5+6	26.158	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297G	2	SP-7	2060.000	NC	SP8+9,SP5+6	23.743	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297G	3	SP-7	1880.000	NC	SP8+9,SP5+6	23.485	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297G	4	SP-7	105.000	RC	SP8+9,SP5+6	23.886	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297G	5	SP-7	487.000	RC	SP8+9,SP5+6	23.564	NC	1958.783	24.172	98.77
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297H	1	SP-10	1730.000	NC	SP11,SP5+6	23.426	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297H	2	SP-10	1760.000	NC	SP11,SP5+6	24.167	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297H	3	SP-10	2230.000	NC	SP11,SP5+6	23.722	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297H	4	SP-10	1190.000	RC	SP11,SP5+6	24.463	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297H	5	SP-10	180.000	RC	SP11,SP5+6	23.357	ND	1823.326	23.827	98.69
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297I	1	SP-12	5130.000	NC	SP13+14,SP2+3	20.360	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297I	2	SP-12	1800.000	RC	SP13+14,SP2+3	25.148	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297I	3	SP-12	732.000	RC	SP13+14,SP2+3	20.346	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297I	4	SP-12	870.000	RC	SP13+14,SP2+3	30.320	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6297I	5	SP-12	480.000	RC	SP13+14,SP2+3	20.099	ND	1896.347	23.303	98.77
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460A	1				SP7,SP9	14.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460A	2				SP7,SP9	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460A	3				SP7,SP9	28.725	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460A	4				SP7,SP9	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460A	5				SP7,SP9	10.000	ND		15.127	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
COPPER	7440508	25	UG/L	6297G	1	SP-7	68.000	NC	SP8+9,SP5+6	5.094	NC			
COPPER	7440508	25	UG/L	6297G	2	SP-7	132.000	NC	SP8+9,SP5+6	5.071	NC			
COPPER	7440508	25	UG/L	6297G	3	SP-7	131.000	NC	SP8+9,SP5+6	5.074	NC			
COPPER	7440508	25	UG/L	6297G	4	SP-7	112.000	NC	SP8+9,SP5+6	5.062	NC			
COPPER	7440508	25	UG/L	6297G	5	SP-7	139.000	NC	SP8+9,SP5+6	5.073	NC	117.855	5.075	95.69
COPPER	7440508	25	UG/L	6297H	1	SP-10	93.400	NC	SP11,SP5+6	5.043	ND			
COPPER	7440508	25	UG/L	6297H	2	SP-10	141.000	NC	SP11,SP5+6	5.085	ND			
COPPER	7440508	25	UG/L	6297H	3	SP-10	141.000	NC	SP11,SP5+6	5.108	ND			
COPPER	7440508	25	UG/L	6297H	4	SP-10	86.700	NC	SP11,SP5+6	5.092	ND			
COPPER	7440508	25	UG/L	6297H	5	SP-10	83.500	NC	SP11,SP5+6	5.087	ND	109.822	5.083	95.37
COPPER	7440508	25	UG/L	6297I	1	SP-12	371.000	NC	SP13+14,SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297I	2	SP-12	233.000	NC	SP13+14,SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297I	3	SP-12	267.000	NC	SP13+14,SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297I	4	SP-12	68.200	NC	SP13+14,SP2+3	5.000	ND			
COPPER	7440508	25	UG/L	6297I	5	SP-12	406.000	NC	SP13+14,SP2+3	5.000	ND	296.819	5.000	98.32
COPPER	7440508	25	UG/L	6460A	1				SP7,SP9	1.000	ND			
COPPER	7440508	25	UG/L	6460A	2				SP7,SP9	1.000	ND			
COPPER	7440508	25	UG/L	6460A	3				SP7,SP9	1.000	ND			
COPPER	7440508	25	UG/L	6460A	4				SP7,SP9	1.000	ND			
COPPER	7440508	25	UG/L	6460A	5				SP7,SP9	1.000	ND		1.000	
FECAL STREPTOCOCCUS	C2107	1	/100M	6460A	3				SP7,SP9	2500.000	NC		2500.000	
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297G	1	SP-7	46.700	NC	SP8+9,SP5+6	5.092	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297G	2	SP-7	64.500	NC	SP8+9,SP5+6	5.058	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297G	3	SP-7	72.667	NC	SP8+9,SP5+6	6.640	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297G	4	SP-7	20.497	NC	SP8+9,SP5+6	24.574	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297G	5	SP-7	200.893	NC	SP8+9,SP5+6	8.868	NC	86.761	10.172	88.28
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297H	1	SP-10	5.000	ND	SP11,SP5+6	5.141	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297H	2	SP-10	84.467	NC	SP11,SP5+6	5.077	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297H	3	SP-10	186.267	NC	SP11,SP5+6	7.004	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297H	4	SP-10	93.333	NC	SP11,SP5+6	24.811	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297H	5	SP-10	30.633	NC	SP11,SP5+6	8.873	NC	87.403	10.734	87.72
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297I	1	SP-12	900.000	NC	SP13+14,SP2+3	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297I	2	SP-12	345.000	NC	SP13+14,SP2+3	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297I	3	SP-12	451.000	NC	SP13+14,SP2+3	6.041	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297I	4	SP-12	247.000	NC	SP13+14,SP2+3	15.043	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6297I	5				SP13+14,SP2+3	5.899	ND	501.351	7.875	98.43
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460A	1				SP7,SP9	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460A	2				SP7,SP9	5.500	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460A	3				SP7,SP9	6.000	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460A	4				SP7,SP9	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460A	5				SP7,SP9	6.000	ND		5.900	
HEXANOIC ACID	142621	10	UG/L	6297G	1	SP-7	109.000	NC	SP8+9,SP5+6	11.040	NC			
HEXANOIC ACID	142621	10	UG/L	6297G	3	SP-7	52.800	NC	SP8+9,SP5+6	10.999	NC			
HEXANOIC ACID	142621	10	UG/L	6297G	5	SP-7	47.600	NC	SP8+9,SP5+6	11.000	NC	71.912	11.013	84.69
HEXANOIC ACID	142621	10	UG/L	6297H	1	SP-10	38.100	NC	SP11,SP5+6	10.744	ND			
HEXANOIC ACID	142621	10	UG/L	6297H	3	SP-10	75.800	NC	SP11,SP5+6	10.918	ND			
HEXANOIC ACID	142621	10	UG/L	6297H	5	SP-10	24.400	NC	SP11,SP5+6	11.303	ND	48.619	10.989	77.40
HEXANOIC ACID	142621	10	UG/L	6297I	1	SP-12	33.100	NC	SP13+14,SP2+3	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297I	3	SP-12	456.000	NC	SP13+14,SP2+3	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6297I	5	SP-12	239.500	NC	SP13+14,SP2+3	10.000	ND	390.639	10.000	97.44
HEXANOIC ACID	142621	10	UG/L	6460A	1				SP7,SP9	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6460A	3				SP7,SP9	10.000	ND		10.000	
IRON	7439896	100	UG/L	6297G	1	SP-7	885.000	NC	SP8+9,SP5+6	51.792	NC			
IRON	7439896	100	UG/L	6297G	2	SP-7	2440.000	NC	SP8+9,SP5+6	51.782	NC			
IRON	7439896	100	UG/L	6297G	3	SP-7	2260.000	NC	SP8+9,SP5+6	51.772	NC			
IRON	7439896	100	UG/L	6297G	4	SP-7	1500.000	NC	SP8+9,SP5+6	51.584	NC			
IRON	7439896	100	UG/L	6297G	5	SP-7	2930.000	NC	SP8+9,SP5+6	51.663	NC	2070.117	51.719	97.50
IRON	7439896	100	UG/L	6297H	1	SP-10	1390.000	NC	SP11,SP5+6	52.113	ND			
IRON	7439896	100	UG/L	6297H	2	SP-10	2230.000	NC	SP11,SP5+6	52.271	ND			
IRON	7439896	100	UG/L	6297H	3	SP-10	1890.000	NC	SP11,SP5+6	52.162	ND			
IRON	7439896	100	UG/L	6297H	4	SP-10	1270.000	NC	SP11,SP5+6	52.044	ND			
IRON	7439896	100	UG/L	6297H	5	SP-10	1260.000	NC	SP11,SP5+6	52.300	ND	1617.388	52.178	96.77
IRON	7439896	100	UG/L	6297I	1	SP-12	5590.000	NC	SP13+14,SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297I	2	SP-12	7210.000	NC	SP13+14,SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297I	3	SP-12	5580.000	NC	SP13+14,SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297I	4	SP-12	2230.000	NC	SP13+14,SP2+3	50.000	ND			
IRON	7439896	100	UG/L	6297I	5	SP-12	7150.000	NC	SP13+14,SP2+3	50.000	ND	5776.343	50.000	99.13
IRON	7439896	100	UG/L	6460A	1				SP7,SP9	87.100	NC			
IRON	7439896	100	UG/L	6460A	2				SP7,SP9	92.900	NC			
IRON	7439896	100	UG/L	6460A	3				SP7,SP9	458.818	NC			
IRON	7439896	100	UG/L	6460A	4				SP7,SP9	27.500	NC			
IRON	7439896	100	UG/L	6460A	5				SP7,SP9	25.600	NC		152.229	
MANGANESE	7439965	15	UG/L	6297G	1	SP-7	166.000	NC	SP8+9,SP5+6	6.554	NC			
MANGANESE	7439965	15	UG/L	6297G	2	SP-7	593.000	NC	SP8+9,SP5+6	6.366	NC			
MANGANESE	7439965	15	UG/L	6297G	3	SP-7	463.000	NC	SP8+9,SP5+6	6.396	NC			
MANGANESE	7439965	15	UG/L	6297G	4	SP-7	286.000	NC	SP8+9,SP5+6	6.351	NC			
MANGANESE	7439965	15	UG/L	6297G	5	SP-7	551.000	NC	SP8+9,SP5+6	6.347	NC	429.666	6.403	98.51

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
MANGANESE	7439965	15	UG/L	6297H	1	SP-10	352.000	NC	SP11,SP5+6	6.629	ND			
MANGANESE	7439965	15	UG/L	6297H	2	SP-10	642.000	NC	SP11,SP5+6	6.728	ND			
MANGANESE	7439965	15	UG/L	6297H	3	SP-10	575.000	NC	SP11,SP5+6	6.876	ND			
MANGANESE	7439965	15	UG/L	6297H	4	SP-10	330.000	NC	SP11,SP5+6	6.827	ND			
MANGANESE	7439965	15	UG/L	6297H	5	SP-10	280.000	NC	SP11,SP5+6	6.718	ND	441.278	6.755	98.47
MANGANESE	7439965	15	UG/L	6297I	1	SP-12	1350.000	NC	SP13+14,SP2+3	5.043	ND			
MANGANESE	7439965	15	UG/L	6297I	2	SP-12	882.000	NC	SP13+14,SP2+3	5.049	ND			
MANGANESE	7439965	15	UG/L	6297I	3	SP-12	1190.000	NC	SP13+14,SP2+3	5.036	ND			
MANGANESE	7439965	15	UG/L	6297I	4	SP-12	463.000	NC	SP13+14,SP2+3	5.037	ND			
MANGANESE	7439965	15	UG/L	6297I	5	SP-12	1740.000	NC	SP13+14,SP2+3	5.049	ND	1168.254	5.043	99.57
MANGANESE	7439965	15	UG/L	6460A	1				SP7,SP9	18.500	NC			
MANGANESE	7439965	15	UG/L	6460A	2				SP7,SP9	18.200	NC			
MANGANESE	7439965	15	UG/L	6460A	3				SP7,SP9	34.483	NC			
MANGANESE	7439965	15	UG/L	6460A	4				SP7,SP9	7.600	NC			
MANGANESE	7439965	15	UG/L	6460A	5				SP7,SP9	6.000	NC		18.033	
NITRATE/NITRITE	C005	0.01	MG/L	6297G	1	SP-7	0.750	NC	SP8+9,SP5+6	1.045	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297G	2	SP-7	1.260	NC	SP8+9,SP5+6	0.995	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297G	3	SP-7	0.720	NC	SP8+9,SP5+6	0.963	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297G	4	SP-7	0.870	NC	SP8+9,SP5+6	1.032	ND			
NITRATE/NITRITE	C005	0.01	MG/L	6297G	5	SP-7	0.740	NC	SP8+9,SP5+6	1.082	ND	0.871	1.023	-17.45
NITRATE/NITRITE	C005	0.01	MG/L	6297H	1	SP-10	0.720	NC	SP11,SP5+6	1.045	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297H	2	SP-10	0.740	NC	SP11,SP5+6	0.993	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297H	3	SP-10	1.090	NC	SP11,SP5+6	0.980	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297H	4	SP-10	0.770	NC	SP11,SP5+6	1.032	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297H	5	SP-10	0.780	NC	SP11,SP5+6	1.082	NC	0.822	1.026	-24.90
NITRATE/NITRITE	C005	0.01	MG/L	6297I	1	SP-12	0.940	NC	SP13+14,SP2+3	1.032	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297I	2	SP-12	0.960	NC	SP13+14,SP2+3	0.963	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297I	3	SP-12	0.850	NC	SP13+14,SP2+3	0.933	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297I	4	SP-12	0.740	NC	SP13+14,SP2+3	1.101	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6297I	5	SP-12	0.830	NC	SP13+14,SP2+3	1.042	NC	0.865	1.015	-17.32
NITRATE/NITRITE	C005	0.01	MG/L	6460A	1				SP7,SP9	0.140	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460A	2				SP7,SP9	0.160	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460A	3				SP7,SP9	0.118	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460A	4				SP7,SP9	0.750	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460A	5				SP7,SP9	0.670	NC		0.400	
SELENIUM	7782492	5	UG/L	6297G	1	SP-7	2.500	NC	SP8+9,SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297G	2	SP-7	2.000	ND	SP8+9,SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297G	3	SP-7	4.600	NC	SP8+9,SP5+6	2.396	ND			
SELENIUM	7782492	5	UG/L	6297G	4	SP-7	3.720	NC	SP8+9,SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297G	5	SP-7	4.520	NC	SP8+9,SP5+6	2.000	ND	3.505	2.079	40.69

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
SELENIUM	7782492	5	UG/L	6297H	1	SP-10	2.100	NC	SP11,SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297H	2	SP-10	2.000	ND	SP11,SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297H	3	SP-10	3.200	NC	SP11,SP5+6	2.416	NC			
SELENIUM	7782492	5	UG/L	6297H	4	SP-10	2.000	ND	SP11,SP5+6	2.000	ND			
SELENIUM	7782492	5	UG/L	6297H	5	SP-10	2.000	ND	SP11,SP5+6	2.000	ND	2.284	2.083	8.79
SELENIUM	7782492	5	UG/L	6297I	1	SP-12	6.200	NC	SP13+14,SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297I	2	SP-12	6.940	NC	SP13+14,SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297I	3	SP-12	8.160	NC	SP13+14,SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297I	4	SP-12	30.500	NC	SP13+14,SP2+3	2.000	ND			
SELENIUM	7782492	5	UG/L	6297I	5	SP-12	8.500	NC	SP13+14,SP2+3	2.000	ND	12.094	2.000	83.46
SELENIUM	7782492	5	UG/L	6460A	1				SP7,SP9	2.000	ND			
SELENIUM	7782492	5	UG/L	6460A	2				SP7,SP9	2.000	ND			
SELENIUM	7782492	5	UG/L	6460A	3				SP7,SP9	2.000	ND			
SELENIUM	7782492	5	UG/L	6460A	4				SP7,SP9	2.000	ND			
SELENIUM	7782492	5	UG/L	6460A	5				SP7,SP9	2.000	ND		2.000	
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297G	1	SP-7	70.000	NC	SP8+9,SP5+6	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297G	2				SP8+9,SP5+6	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297G	3	SP-7	50.000	NC	SP8+9,SP5+6	1.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297G	4	SP-7	59.000	NC	SP8+9,SP5+6	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297G	5	SP-7	105.000	NC	SP8+9,SP5+6	0.100	ND	71.788	0.280	99.61
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297H	1	SP-10	21.000	NC	SP11,SP5+6	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297H	2				SP11,SP5+6	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297H	3	SP-10	69.000	NC	SP11,SP5+6	1.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297H	4	SP-10	41.000	NC	SP11,SP5+6	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297H	5	SP-10	31.000	NC	SP11,SP5+6	2.000	NC	41.750	0.698	98.33
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297I	1	SP-12	95.000	NC	SP13+14,SP2+3	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297I	2				SP13+14,SP2+3	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297I	3				SP13+14,SP2+3	1.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297I	4	SP-12	98.000	NC						
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6297I	5				SP13+14,SP2+3	1.000	NC	96.500	0.550	99.43
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6460A	3				SP7,SP9	0.200	NC		0.200	
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	1				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	33				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	67				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	95				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	127				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	155				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	246				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	281				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	307				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	340				SP-1	0.100	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	371				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	399				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	523				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	617				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	677				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	795				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	886				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	1071				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR1	1160				SP-1	0.100	ND		0.100	
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	1				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	28				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	58				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	95				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	120				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	148				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	176				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	213				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	242				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	273				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	302				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	340				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	368				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	393				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	424				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	455				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	484				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	518				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	546				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	578				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	611				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	639				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	667				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	700				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	730				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	758				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	788				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	822				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	854				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	883				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	913				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	947				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	977				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	1008				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	1036				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	1070				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR3	1100				SP-1	0.100	ND		0.100	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	28				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	57				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	87				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	184				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	212				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	246				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	275				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	304				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	336				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	367				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	394				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	426				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	459				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	490				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	517				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	547				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	576				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	611				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	639				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	672				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	702				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	734				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	756				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	794				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	820				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	854				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	882				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	916				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	917				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	939				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	973				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	1004				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	1030				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	1065				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR4	1092				SP-1	0.100	ND		0.100	
TOTAL COLIFORM	E10606	1	/100M	6460A	3				SP7,SP9	460.000	NC		460.000	
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297G	1	SP-7	69.100	NC	SP8+9,SP5+6	0.806	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297G	2	SP-7	57.500	NC	SP8+9,SP5+6	6.734	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297G	3	SP-7	142.000	NC	SP8+9,SP5+6	0.803	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297G	4	SP-7	12.500	NC	SP8+9,SP5+6	0.770	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297G	5	SP-7	34.300	NC	SP8+9,SP5+6	0.733	NC	71.441	1.909	97.33
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297H	1	SP-10	37.300	NC	SP11,SP5+6	0.665	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297H	2	SP-10	67.500	NC	SP11,SP5+6	6.741	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297H	3	SP-10	98.600	NC	SP11,SP5+6	0.812	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297H	4	SP-10	14.300	NC	SP11,SP5+6	0.765	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297H	5	SP-10	13.200	NC	SP11,SP5+6	0.727	NC	51.405	1.881	96.34
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297I	1	SP-12	4.230	NC	SP13+14,SP2+3	0.545	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297I	2	SP-12	96.700	NC	SP13+14,SP2+3	1.814	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297I	3	SP-12	68.000	NC	SP13+14,SP2+3	0.536	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297I	4	SP-12	29.100	NC	SP13+14,SP2+3	0.537	ND			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6297I	5	SP-12	37.900	NC	SP13+14,SP2+3	0.544	ND	65.893	0.795	98.79
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460A	1				SP7,SP9	0.330	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460A	2				SP7,SP9	0.250	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460A	3				SP7,SP9	1.590	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460A	4				SP7,SP9	0.220	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460A	5				SP7,SP9	0.310	NC		0.538	
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297G	1	SP-7	6.380	NC	SP8+9,SP5+6	0.297	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297G	2	SP-7	17.300	NC	SP8+9,SP5+6	0.262	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297G	3	SP-7	8.480	NC	SP8+9,SP5+6	0.183	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297G	4	SP-7	9.120	NC	SP8+9,SP5+6	0.424	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297G	5	SP-7	8.010	NC	SP8+9,SP5+6	0.239	NC	9.938	0.283	97.15
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297H	1	SP-10	7.280	NC	SP11,SP5+6	0.273	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297H	2	SP-10	10.100	NC	SP11,SP5+6	0.267	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297H	3	SP-10	11.000	NC	SP11,SP5+6	0.196	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297H	4	SP-10	4.690	NC	SP11,SP5+6	0.422	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297H	5	SP-10	3.150	NC	SP11,SP5+6	0.230	NC	7.516	0.279	96.28
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297I	1	SP-12	18.400	NC	SP13+14,SP2+3	0.101	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297I	2	SP-12	4.300	NC	SP13+14,SP2+3	0.177	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297I	3	SP-12	24.600	NC	SP13+14,SP2+3	0.053	ND			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297I	4	SP-12	8.210	NC	SP13+14,SP2+3	0.213	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6297I	5	SP-12	17.500	NC	SP13+14,SP2+3	0.090	NC	15.841	0.130	99.18
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460A	1				SP7,SP9	0.030	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460A	2				SP7,SP9	0.030	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460A	3				SP7,SP9	0.303	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460A	4				SP7,SP9	0.020	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460A	5				SP7,SP9	0.010	NC		0.080	
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297G	1	SP-7	10.500	RC	SP8+9,SP5+6	0.282	RC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297G	2	SP-7	41.300	NC	SP8+9,SP5+6	0.341	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297G	3	SP-7	41.800	NC	SP8+9,SP5+6	0.337	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297G	4	SP-7	17.900	NC	SP8+9,SP5+6	0.145	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297G	5	SP-7	19.500	NC	SP8+9,SP5+6	0.244	NC	27.320	0.275	98.99
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297H	1	SP-10	10.500	RC	SP11,SP5+6	0.263	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297H	2	SP-10	22.900	NC	SP11,SP5+6	0.342	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297H	3	SP-10	0.200	NC	SP11,SP5+6	0.344	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297H	4	SP-10	16.700	NC	SP11,SP5+6	0.134	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297H	5	SP-10	10.100	NC	SP11,SP5+6	0.231	NC	39.427	0.264	99.33
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297I	1	SP-12	10.500	RC	SP13+14,SP2+3	0.055	ND			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297I	2	SP-12	25.400	NC	SP13+14,SP2+3	0.265	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297I	3	SP-12	2.340	NC	SP13+14,SP2+3	0.135	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297I	4	SP-12	80.400	NC	SP13+14,SP2+3	0.093	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6297I	5	SP-12	76.000	NC	SP13+14,SP2+3	0.101	NC	62.131	0.132	99.79
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460A	1				SP7,SP9	0.060	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460A	2				SP7,SP9	0.060	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460A	3				SP7,SP9	0.301	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460A	4				SP7,SP9	0.030	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460A	5				SP7,SP9	0.030	NC		0.098	
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	1				SP-1	0.040	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	33				SP-1	0.010	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	67				SP-1	0.040	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	95				SP-1	0.040	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	127				SP-1	0.040	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	155				SP-1	0.050	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	246				SP-1	0.070	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	281				SP-1	0.070	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	307				SP-1	0.540	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	340				SP-1	0.090	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	371				SP-1	0.130	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR1	399				SP-1	0.060	NC		0.093	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297G	1	SP-7	1000.000	NC	SP8+9,SP5+6	4.653	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297G	2	SP-7	553.000	NC	SP8+9,SP5+6	4.396	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297G	3	SP-7	1040.000	NC	SP8+9,SP5+6	4.416	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297G	4	SP-7	1710.000	NC	SP8+9,SP5+6	4.644	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297G	5	SP-7	363.000	NC	SP8+9,SP5+6	4.554	NC	976.155	4.533	99.54
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297H	1	SP-10	1040.000	NC	SP11,SP5+6	4.513	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297H	2	SP-10	687.000	NC	SP11,SP5+6	4.632	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297H	3	SP-10	4.000	ND	SP11,SP5+6	4.691	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297H	4	SP-10	540.000	NC	SP11,SP5+6	4.671	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297H	5	SP-10	690.000	NC	SP11,SP5+6	4.731	ND	597.100	4.648	99.22
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297I	1	SP-12	4050.000	NC	SP13+14,SP2+3	4.069	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297I	2	SP-12	707.000	NC	SP13+14,SP2+3	4.602	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297I	3	SP-12	2020.000	NC	SP13+14,SP2+3	4.058	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297I	4	SP-12	3360.000	NC	SP13+14,SP2+3	4.075	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6297I	5	SP-12	2830.000	NC	SP13+14,SP2+3	4.044	ND	2829.903	4.170	99.85
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460A	1				SP7,SP9	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460A	2				SP7,SP9	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460A	3				SP7,SP9	31.681	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460A	4				SP7,SP9	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460A	5				SP7,SP9	4.000	ND		9.536	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	1				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	33				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	67				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	95				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	127				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	155				SP-1	5.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	246				SP-1	3.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	281				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	307				SP-1	3.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	340				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	371				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	399				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	523				SP-1	3.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	617				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	677				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	795				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	1071				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	1160				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR1	1168				SP-1	1.000	NC		1.781	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	1				SP-1	3.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	28				SP-1	5.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	58				SP-1	3.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	95				SP-1	4.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	120				SP-1	4.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	148				SP-1	3.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	176				SP-1	3.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	213				SP-1	5.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	242				SP-1	5.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	273				SP-1	2.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	302				SP-1	3.300	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	340				SP-1	3.200	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	368				SP-1	2.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	393				SP-1	5.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	424				SP-1	4.300	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	455				SP-1	4.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	484				SP-1	6.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	518				SP-1	4.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	546				SP-1	3.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	578				SP-1	1.700	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	611				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	639				SP-1	2.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	667				SP-1	2.200	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	700				SP-1	3.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	730				SP-1	2.900	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	758				SP-1	3.200	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	788				SP-1	4.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	822				SP-1	2.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	854				SP-1	3.200	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	883				SP-1	2.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	913				SP-1	1.800	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	947				SP-1	3.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	977				SP-1	7.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	1008				SP-1	4.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	1036				SP-1	4.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	1070				SP-1	4.300	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR3	1100				SP-1	3.900	NC		3.696	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	1				SP-1	1.700	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	28				SP-1	6.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	57				SP-1	4.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	87				SP-1	1.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	119				SP-1	1.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	147				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	184				SP-1	2.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	212				SP-1	2.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	246				SP-1	1.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	275				SP-1	0.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	304				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	336				SP-1	6.300	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	367				SP-1	9.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	426				SP-1	2.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	459				SP-1	2.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	490				SP-1	2.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	517				SP-1	3.300	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	547				SP-1	1.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	576				SP-1	0.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	611				SP-1	1.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	639				SP-1	1.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	672				SP-1	1.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	756				SP-1	1.100	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	794				SP-1	6.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	820				SP-1	3.400	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	854				SP-1	4.200	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	882				SP-1	6.300	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	916				SP-1	2.200	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	939				SP-1	2.900	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	973				SP-1	1.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	1004				SP-1	1.700	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	1030				SP-1	1.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	1065				SP-1	1.600	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR4	1092				SP-1	0.600	NC		2.676	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ZINC	7440666	20	UG/L	6297G	1	SP-7	386.000	NC	SP8+9,SP5+6	6.592	NC			
ZINC	7440666	20	UG/L	6297G	2	SP-7	1060.000	NC	SP8+9,SP5+6	5.574	NC			
ZINC	7440666	20	UG/L	6297G	3	SP-7	952.000	NC	SP8+9,SP5+6	5.643	NC			
ZINC	7440666	20	UG/L	6297G	4	SP-7	1600.000	NC	SP8+9,SP5+6	5.643	NC			
ZINC	7440666	20	UG/L	6297G	5	SP-7	1640.000	NC	SP8+9,SP5+6	5.688	NC	1193.105	5.831	99.51
ZINC	7440666	20	UG/L	6297H	1	SP-10	768.000	NC	SP11,SP5+6	6.452	NC			
ZINC	7440666	20	UG/L	6297H	2	SP-10	1170.000	NC	SP11,SP5+6	5.925	ND			
ZINC	7440666	20	UG/L	6297H	3	SP-10	1070.000	NC	SP11,SP5+6	6.096	ND			
ZINC	7440666	20	UG/L	6297H	4	SP-10	792.000	NC	SP11,SP5+6	5.997	ND			
ZINC	7440666	20	UG/L	6297H	5	SP-10	625.000	NC	SP11,SP5+6	5.888	ND	890.912	6.072	99.32
ZINC	7440666	20	UG/L	6297I	1	SP-12	3350.000	NC	SP13+14,SP2+3	5.103	ND			
ZINC	7440666	20	UG/L	6297I	2	SP-12	2190.000	NC	SP13+14,SP2+3	5.077	ND			
ZINC	7440666	20	UG/L	6297I	3	SP-12	3040.000	NC	SP13+14,SP2+3	5.072	ND			
ZINC	7440666	20	UG/L	6297I	4	SP-12	1180.000	NC	SP13+14,SP2+3	5.058	ND			
ZINC	7440666	20	UG/L	6297I	5	SP-12	3300.000	NC	SP13+14,SP2+3	5.079	ND	2691.931	5.078	99.81
ZINC	7440666	20	UG/L	6460A	1				SP7,SP9	1.800	NC			
ZINC	7440666	20	UG/L	6460A	2				SP7,SP9	1.100	NC			
ZINC	7440666	20	UG/L	6460A	3				SP7,SP9	24.773	NC			
ZINC	7440666	20	UG/L	6460A	4				SP7,SP9	1.900	NC			
ZINC	7440666	20	UG/L	6460A	5				SP7,SP9	2.000	NC		6.086	

Subcategory=Flow-thru -- Option=3

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
AEROMONAS	C2101	1	/100M	6460D	3	SP7,SP8	100000.000	ND	SP10+11	665.500	NC			
AEROMONAS	C2101	1	/100M	6460D	4				SP10+11	270.000	NC			
AEROMONAS	C2101	1	/100M	6460D	5				SP10+11	341.000	NC			
AEROMONAS	C2101	1	/100M	6460D	6				SP10+11	690.000	NC	100000.000	507.312	99.49
ALUMINUM	7429905	200	UG/L	6460D	1	SP7,SP8	48.000	ND	SP10+11	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460D	2	SP7,SP8	48.000	ND	SP10+11	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460D	3	SP7,SP8	2337.343	NC	SP10+11	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460D	4	SP7,SP8	48.000	ND	SP10+11	48.000	ND			
ALUMINUM	7429905	200	UG/L	6460D	5	SP7,SP8	48.000	ND	SP10+11	48.000	ND	505.869	48.000	90.51
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460D	1	SP7,SP8	0.220	NC	SP10+11	0.215	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460D	2	SP7,SP8	0.100	NC	SP10+11	0.070	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460D	3	SP7,SP8	11.420	NC	SP10+11	0.130	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460D	4	SP7,SP8	0.160	NC	SP10+11	0.110	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6460D	5	SP7,SP8	0.120	NC	SP10+11	0.195	NC	2.446	0.148	93.96

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=3
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BARIUM	7440393	200	UG/L	6460D	1	SP7,SP8	22.200	NC	SP10+11	22.400	NC			
BARIUM	7440393	200	UG/L	6460D	2	SP7,SP8	22.000	NC	SP10+11	22.600	NC			
BARIUM	7440393	200	UG/L	6460D	3	SP7,SP8	463.312	NC	SP10+11	22.150	NC			
BARIUM	7440393	200	UG/L	6460D	4	SP7,SP8	17.100	NC	SP10+11	19.200	NC			
BARIUM	7440393	200	UG/L	6460D	5	SP7,SP8	18.000	NC	SP10+11	17.300	NC	101.098	20.762	79.46
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460D	1	SP7,SP8	2.000	ND	SP10+11	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460D	2	SP7,SP8	6.000	ND	SP10+11	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460D	3	SP7,SP8	3248.764	NC	SP10+11	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460D	4	SP7,SP8	2.000	ND	SP10+11	2.000	ND			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6460D	5	SP7,SP8	2.000	ND	SP10+11	2.000	ND	652.153	2.000	99.69
BORON	7440428	100	UG/L	6460D	1	SP7,SP8	30.900	NC	SP10+11	30.600	NC			
BORON	7440428	100	UG/L	6460D	2	SP7,SP8	378.000	NC	SP10+11	16.450	NC			
BORON	7440428	100	UG/L	6460D	3	SP7,SP8	97.254	NC	SP10+11	2.000	ND			
BORON	7440428	100	UG/L	6460D	4	SP7,SP8	2.000	ND	SP10+11	2.000	ND			
BORON	7440428	100	UG/L	6460D	5	SP7,SP8	2.000	ND	SP10+11	2.000	ND	138.149	11.082	91.98
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460D	1	SP7,SP8	14.000	NC	SP10+11	21.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460D	2	SP7,SP8	10.000	ND	SP10+11	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460D	3	SP7,SP8	7410.473	NC	SP10+11	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460D	4	SP7,SP8	10.000	ND	SP10+11	10.000	ND			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6460D	5	SP7,SP8	10.000	ND	SP10+11	21.000	NC	2401928.41	14.400	100.00
COPPER	7440508	25	UG/L	6460D	1	SP7,SP8	1.000	ND	SP10+11	1.000	ND			
COPPER	7440508	25	UG/L	6460D	2	SP7,SP8	1.000	ND	SP10+11	1.000	ND			
COPPER	7440508	25	UG/L	6460D	3	SP7,SP8	156.499	NC	SP10+11	1.000	ND			
COPPER	7440508	25	UG/L	6460D	4	SP7,SP8	1.000	ND	SP10+11	1.000	ND			
COPPER	7440508	25	UG/L	6460D	5	SP7,SP8	1.000	ND	SP10+11	1.000	ND	32.100	1.000	96.88
FECAL STREPTOCOCCUS	C2107	1	/100M	6460D	3	SP7,SP8	2900000.00	NC	SP10+11	370.000	NC			
FECAL STREPTOCOCCUS	C2107	1	/100M	6460D	4				SP10+11	221.000	NC			
FECAL STREPTOCOCCUS	C2107	1	/100M	6460D	5				SP10+11	120.000	NC			
FECAL STREPTOCOCCUS	C2107	1	/100M	6460D	6				SP10+11	730.000	NC	2900000.00	390.352	99.99
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460D	1	SP7,SP8	6.000	ND	SP10+11	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460D	2	SP7,SP8	5.500	ND	SP10+11	5.500	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460D	3	SP7,SP8	599.503	NC	SP10+11	5.250	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460D	4	SP7,SP8	6.000	ND	SP10+11	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6460D	5	SP7,SP8	6.000	ND	SP10+11	6.000	ND	124.601	5.550	95.55
HEXANOIC ACID	142621	10	UG/L	6460D	1	SP7,SP8	10.000	ND	SP10+11	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6460D	3	SP7,SP8	787.497	NC	SP10+11	10.000	ND	398.749	10.000	97.49
IRON	7439896	100	UG/L	6460D	1	SP7,SP8	87.100	NC	SP10+11	101.150	NC			
IRON	7439896	100	UG/L	6460D	2	SP7,SP8	92.900	NC	SP10+11	88.100	NC			
IRON	7439896	100	UG/L	6460D	3	SP7,SP8	26218.814	NC	SP10+11	105.300	NC			
IRON	7439896	100	UG/L	6460D	4	SP7,SP8	27.500	NC	SP10+11	37.600	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=3
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
IRON	7439896	100	UG/L	6460D	5	SP7,SP8	25.600	NC	SP10+11	34.650	NC	10758.373	76.462	99.29
MANGANESE	7439965	15	UG/L	6460D	1	SP7,SP8	18.500	NC	SP10+11	15.200	NC			
MANGANESE	7439965	15	UG/L	6460D	2	SP7,SP8	18.200	NC	SP10+11	15.450	NC			
MANGANESE	7439965	15	UG/L	6460D	3	SP7,SP8	3249.415	NC	SP10+11	17.500	NC			
MANGANESE	7439965	15	UG/L	6460D	4	SP7,SP8	7.600	NC	SP10+11	7.800	NC			
MANGANESE	7439965	15	UG/L	6460D	5	SP7,SP8	6.000	NC	SP10+11	6.150	NC	988.017	12.792	98.71
NITRATE/NITRITE	C005	0.01	MG/L	6460D	1	SP7,SP8	0.140	NC	SP10+11	0.155	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460D	2	SP7,SP8	0.160	NC	SP10+11	0.145	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460D	3	SP7,SP8	0.492	NC	SP10+11	0.220	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460D	4	SP7,SP8	0.750	NC	SP10+11	0.710	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6460D	5	SP7,SP8	0.670	NC	SP10+11	0.685	NC	0.488	0.408	16.28
SELENIUM	7782492	5	UG/L	6460D	1	SP7,SP8	2.000	ND	SP10+11	2.000	ND			
SELENIUM	7782492	5	UG/L	6460D	2	SP7,SP8	2.000	ND	SP10+11	2.000	ND			
SELENIUM	7782492	5	UG/L	6460D	3	SP7,SP8	9.327	NC	SP10+11	2.000	ND			
SELENIUM	7782492	5	UG/L	6460D	4	SP7,SP8	2.000	ND	SP10+11	2.000	ND			
SELENIUM	7782492	5	UG/L	6460D	5	SP7,SP8	2.000	ND	SP10+11	2.000	ND	3.465	2.000	42.29
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6460D	3	SP7,SP8	240.000	NC				240.000		
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	1				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	27				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	58				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	86				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	126				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	210				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	244				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	273				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	297				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	394				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	492				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	576				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	666				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	764				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	849				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	941				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	1035				SP-1	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	DMR2	1128				SP-1	0.100	ND		0.100	
TOTAL COLIFORM	E10606	1	/100M	6460D	3	SP7,SP8	10900.000	NC	SP10+11	505.000	NC			
TOTAL COLIFORM	E10606	1	/100M	6460D	4				SP10+11	485.000	NC			
TOTAL COLIFORM	E10606	1	/100M	6460D	5				SP10+11	1.000	ND			
TOTAL COLIFORM	E10606	1	/100M	6460D	6				SP10+11	126.000	NC	10900.000	321.683	97.05
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460D	1	SP7,SP8	0.330	NC	SP10+11	0.350	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460D	2	SP7,SP8	0.250	NC	SP10+11	0.290	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=3 (continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460D	3	SP7,SP8	55.729	NC	SP10+11	0.190	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460D	4	SP7,SP8	0.220	NC	SP10+11	0.260	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6460D	5	SP7,SP8	0.310	NC	SP10+11	0.280	NC	13.557	0.276	97.97
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460D	1	SP7,SP8	0.030	NC	SP10+11	0.020	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460D	2	SP7,SP8	0.030	NC	SP10+11	0.020	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460D	3	SP7,SP8	27.113	NC	SP10+11	0.010	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460D	4	SP7,SP8	0.020	NC	SP10+11	0.010	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6460D	5	SP7,SP8	0.010	NC	SP10+11	0.010	NC	16.670	0.014	99.91
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460D	1	SP7,SP8	0.060	NC	SP10+11	0.060	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460D	2	SP7,SP8	0.060	NC	SP10+11	0.050	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460D	3	SP7,SP8	49.751	NC	SP10+11	0.045	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460D	4	SP7,SP8	0.030	NC	SP10+11	0.040	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6460D	5	SP7,SP8	0.030	NC	SP10+11	0.035	NC	27.323	0.046	99.83
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	1				SP-1	0.010	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	27				SP-1	0.150	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	58				SP-1	0.140	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	86				SP-1	0.200	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	126				SP-1	0.200	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	210				SP-1	0.130	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	244				SP-1	0.200	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	273				SP-1	0.300	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	DMR2	297				SP-1	0.170	NC		0.215	
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460D	1	SP7,SP8	4.000	ND	SP10+11	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460D	2	SP7,SP8	4.000	ND	SP10+11	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460D	3	SP7,SP8	9607.518	NC	SP10+11	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460D	4	SP7,SP8	4.000	ND	SP10+11	4.000	ND			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6460D	5	SP7,SP8	4.000	ND	SP10+11	4.000	ND	1924.704	4.000	99.79
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	1				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	27				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	86				SP-1	7.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	210				SP-1	3.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	244				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	273				SP-1	9.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	297				SP-1	3.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	394				SP-1	12.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	492				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	576				SP-1	2.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	666				SP-1	4.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	764				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	849				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	941				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	1035				SP-1	1.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	DMR2	1128				SP-1	1.000	NC		3.124	

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Flow-thru -- Option=3
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ZINC	7440666	20	UG/L	6460D	1	SP7,SP8	1.800	NC	SP10+11	1.150	NC			
ZINC	7440666	20	UG/L	6460D	2	SP7,SP8	1.100	NC	SP10+11	1.150	NC			
ZINC	7440666	20	UG/L	6460D	3	SP7,SP8	3069.469	NC	SP10+11	3.900	NC			
ZINC	7440666	20	UG/L	6460D	4	SP7,SP8	1.900	NC	SP10+11	1.000	ND			
ZINC	7440666	20	UG/L	6460D	5	SP7,SP8	2.000	NC	SP10+11	6.850	NC	2208.876	3.118	99.86

Subcategory=Recirculating -- Option=NA

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
AEROMONAS	C2101	1	/100M	6439C	1	SP-2	60000.000	NC						
AEROMONAS	C2101	1	/100M	6439C	2	SP-2	200000.000	RC						
AEROMONAS	C2101	1	/100M	6439C	3	SP-2	76500.000	NC						
AEROMONAS	C2101	1	/100M	6439C	4	SP-2	35000.000	NC						
AEROMONAS	C2101	1	/100M	6439C	5	SP-2	42400.000	NC				84654.980		
ALUMINUM	7429905	200	UG/L	6439C	1	SP-2	17.000	ND						
ALUMINUM	7429905	200	UG/L	6439C	2	SP-2	54.000	NC						
ALUMINUM	7429905	200	UG/L	6439C	3	SP-2	17.000	ND						
ALUMINUM	7429905	200	UG/L	6439C	4	SP-2	17.000	ND						
ALUMINUM	7429905	200	UG/L	6439C	5	SP-2	17.000	ND				24.400		
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439C	1	SP-2	1.100	NC						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439C	2	SP-2	2.080	NC						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439C	3	SP-2	1.380	NC						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439C	4	SP-2	1.200	NC						
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439C	5	SP-2	1.090	NC				1.377		
BARIUM	7440393	200	UG/L	6439C	1	SP-2	27.100	NC						
BARIUM	7440393	200	UG/L	6439C	2	SP-2	27.700	NC						
BARIUM	7440393	200	UG/L	6439C	3	SP-2	28.600	NC						
BARIUM	7440393	200	UG/L	6439C	4	SP-2	26.400	NC						
BARIUM	7440393	200	UG/L	6439C	5	SP-2	28.000	NC				27.563		
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439C	1	SP-2	59.000	NC						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439C	2	SP-2	38.000	NC						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439C	3	SP-2	51.000	NC						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439C	4	SP-2	47.000	NC						
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439C	5	SP-2	49.000	NC				48.934		
BORON	7440428	100	UG/L	6439C	1	SP-2	236.000	NC						
BORON	7440428	100	UG/L	6439C	2	SP-2	263.000	NC						
BORON	7440428	100	UG/L	6439C	3	SP-2	309.000	NC						
BORON	7440428	100	UG/L	6439C	4	SP-2	264.000	NC						

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BORON	7440428	100	UG/L	6439C	5	SP-2	279.000	NC				270.458		
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439C	1	SP-2	95.000	NC						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439C	2	SP-2	118.000	NC						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439C	3	SP-2	116.000	NC						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439C	4	SP-2	79.000	NC						
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439C	5	SP-2	59.000	NC				94.350		
COPPER	7440508	25	UG/L	6439C	1	SP-2	16.600	NC						
COPPER	7440508	25	UG/L	6439C	2	SP-2	15.900	NC						
COPPER	7440508	25	UG/L	6439C	3	SP-2	17.600	NC						
COPPER	7440508	25	UG/L	6439C	4	SP-2	14.000	NC						
COPPER	7440508	25	UG/L	6439C	5	SP-2	15.400	NC				15.912		
FECAL STREPTOCOCCUS	C2107	1	/100M	6439C	1	SP-2	5100.000	NC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439C	2	SP-2	200000.000	RC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439C	3	SP-2	26000.000	NC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439C	4	SP-2	34000.000	NC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439C	5	SP-2	13000.000	NC				65130.942		
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439C	0	SP-2	5.000	ND						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439C	1	SP-2	5.000	ND						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439C	2	SP-2	5.000	ND						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439C	3	SP-2	7.500	NC						
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439C	4	SP-2	9.000	NC				6.314		
HEXANOIC ACID	142621	10	UG/L	6439C	1	SP-2	10.000	ND						
HEXANOIC ACID	142621	10	UG/L	6439C	3	SP-2	10.000	ND				10.000		
IRON	7439896	100	UG/L	6439C	1	SP-2	79.500	NC						
IRON	7439896	100	UG/L	6439C	2	SP-2	146.000	NC						
IRON	7439896	100	UG/L	6439C	3	SP-2	141.000	NC						
IRON	7439896	100	UG/L	6439C	4	SP-2	91.900	NC						
IRON	7439896	100	UG/L	6439C	5	SP-2	12.000	ND				95.217		
MANGANESE	7439965	15	UG/L	6439C	1	SP-2	53.200	NC						
MANGANESE	7439965	15	UG/L	6439C	2	SP-2	160.000	NC						
MANGANESE	7439965	15	UG/L	6439C	3	SP-2	128.000	NC						
MANGANESE	7439965	15	UG/L	6439C	4	SP-2	100.000	NC						
MANGANESE	7439965	15	UG/L	6439C	5	SP-2	119.000	NC				114.919		
NITRATE/NITRITE	C005	0.01	MG/L	6439C	1	SP-2	112.000	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6439C	2	SP-2	98.800	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6439C	3	SP-2	116.000	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6439C	4	SP-2	133.000	NC						
NITRATE/NITRITE	C005	0.01	MG/L	6439C	5	SP-2	132.000	NC				118.551		
SELENIUM	7782492	5	UG/L	6439C	1	SP-2	2.500	NC						

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=NA
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
SELENIUM	7782492	5	UG/L	6439C	2	SP-2	20.000	ND						
SELENIUM	7782492	5	UG/L	6439C	3	SP-2	20.000	ND						
SELENIUM	7782492	5	UG/L	6439C	4	SP-2	2.000	ND						
SELENIUM	7782492	5	UG/L	6439C	5	SP-2	2.000	ND				9.300		
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439C	1	SP-2	0.100	ND						
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439C	2	SP-2	0.100	ND						
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439C	3	SP-2	0.300	NC						
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439C	4	SP-2	0.100	ND						
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439C	5	SP-2	0.100	ND				0.140		
TOTAL COLIFORM	E10606	1	/100M	6439C	1	SP-2	2900.000	NC						
TOTAL COLIFORM	E10606	1	/100M	6439C	2	SP-2	200000.000	RC						
TOTAL COLIFORM	E10606	1	/100M	6439C	3	SP-2	4200.000	NC						
TOTAL COLIFORM	E10606	1	/100M	6439C	4	SP-2	200000.000	RC						
TOTAL COLIFORM	E10606	1	/100M	6439C	5	SP-2	28000.000	NC				209212.560		
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439C	1	SP-2	2.760	NC						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439C	2	SP-2	3.090	NC						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439C	3	SP-2	6.650	NC						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439C	4	SP-2	3.530	NC						
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439C	5	SP-2	3.020	NC				3.833		
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439C	1	SP-2	12.600	NC						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439C	2	SP-2	8.830	NC						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439C	3	SP-2	10.500	NC						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439C	4	SP-2	9.060	NC						
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439C	5	SP-2	8.720	NC				9.963		
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439C	1	SP-2	14.100	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439C	2	SP-2	11.100	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439C	3	SP-2	11.900	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439C	4	SP-2	10.500	NC						
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439C	5	SP-2	8.830	NC				11.319		
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439C	1	SP-2	38.000	NC						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439C	2	SP-2	45.000	NC						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439C	3	SP-2	49.000	NC						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439C	4	SP-2	55.000	NC						
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439C	5	SP-2	44.000	NC				46.288		
ZINC	7440666	20	UG/L	6439C	1	SP-2	34.800	NC						
ZINC	7440666	20	UG/L	6439C	2	SP-2	38.200	NC						
ZINC	7440666	20	UG/L	6439C	3	SP-2	47.300	NC						
ZINC	7440666	20	UG/L	6439C	4	SP-2	38.100	NC						
ZINC	7440666	20	UG/L	6439C	5	SP-2	1.000	ND				31.942		

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=1

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ALUMINUM	7429905	200	UG/L	6439A	1	SP-3	247.000	NC	SP-4	74.300	NC			
ALUMINUM	7429905	200	UG/L	6439A	2	SP-3	551.000	NC	SP-4	67.700	NC			
ALUMINUM	7429905	200	UG/L	6439A	3	SP-3	583.000	NC	SP-4	17.000	ND			
ALUMINUM	7429905	200	UG/L	6439A	4	SP-3	431.000	NC	SP-4	779.000	NC			
ALUMINUM	7429905	200	UG/L	6439A	5	SP-3	311.000	NC	SP-4	104.000	NC	431.484	223.416	48.22
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439A	1	SP-3	1.870	NC	SP-4	2.180	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439A	2	SP-3	3.050	NC	SP-4	3.010	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439A	3	SP-3	2.910	NC	SP-4	2.610	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439A	4	SP-3	1.650	NC	SP-4	3.690	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439A	5	SP-3	1.600	NC	SP-4	1.100	NC	2.236	2.600	-16.27
BARIUM	7440393	200	UG/L	6439A	1	SP-3	60.900	NC	SP-4	38.200	NC			
BARIUM	7440393	200	UG/L	6439A	2	SP-3	83.900	NC	SP-4	41.100	NC			
BARIUM	7440393	200	UG/L	6439A	3	SP-3	94.000	NC	SP-4	40.500	NC			
BARIUM	7440393	200	UG/L	6439A	4	SP-3	73.200	NC	SP-4	109.000	NC			
BARIUM	7440393	200	UG/L	6439A	5	SP-3	73.400	NC	SP-4	42.900	NC	77.291	54.613	29.34
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439A	1	SP-3	198.000	NC	SP-4	68.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439A	2	SP-3	207.000	RC	SP-4	80.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439A	3	SP-3	542.000	NC	SP-4	94.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439A	4	SP-3	624.000	NC	SP-4	616.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439A	5	SP-3	207.000	RC	SP-4	94.000	NC	366.176	187.123	48.90
BORON	7440428	100	UG/L	6439A	1	SP-3	203.000	NC	SP-4	208.000	NC			
BORON	7440428	100	UG/L	6439A	2	SP-3	258.000	NC	SP-4	214.000	NC			
BORON	7440428	100	UG/L	6439A	3	SP-3	228.000	NC	SP-4	234.000	NC			
BORON	7440428	100	UG/L	6439A	4	SP-3	261.000	NC	SP-4	270.000	NC			
BORON	7440428	100	UG/L	6439A	5	SP-3	278.000	NC	SP-4	258.000	NC	246.022	237.104	3.62
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439A	1	SP-3	675.000	NC	SP-4	134.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439A	2	SP-3	1100.000	NC	SP-4	185.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439A	3	SP-3	880.000	NC	SP-4	141.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439A	4	SP-3	666.000	NC	SP-4	652.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439A	5	SP-3	532.000	NC	SP-4	136.000	NC	776.297	249.919	67.81
COPPER	7440508	25	UG/L	6439A	1	SP-3	51.300	NC	SP-4	21.000	NC			
COPPER	7440508	25	UG/L	6439A	2	SP-3	72.400	NC	SP-4	20.400	NC			
COPPER	7440508	25	UG/L	6439A	3	SP-3	83.500	NC	SP-4	21.600	NC			
COPPER	7440508	25	UG/L	6439A	4	SP-3	69.800	NC	SP-4	163.000	NC			
COPPER	7440508	25	UG/L	6439A	5	SP-3	74.300	NC	SP-4	23.900	NC	70.541	48.848	30.75
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439A	0	SP-3	7.500	NC	SP-4	5.500	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439A	1	SP-3	17.500	NC	SP-4	7.000	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439A	2	SP-3	7.000	NC	SP-4	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439A	3	SP-3	9.500	NC	SP-4	7.000	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439A	4	SP-3	11.000	NC	SP-4	8.500	NC	10.604	6.623	37.54
HEXANOIC ACID	142621	10	UG/L	6439A	1	SP-3	10.000	ND	SP-4	10.000	ND			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
HEXANOIC ACID	142621	10	UG/L	6439A	3	SP-3	10.000	ND	SP-4	10.000	ND	10.000	10.000	0.00
IRON	7439896	100	UG/L	6439A	1	SP-3	935.000	NC	SP-4	193.000	NC			
IRON	7439896	100	UG/L	6439A	2	SP-3	1810.000	NC	SP-4	196.000	NC			
IRON	7439896	100	UG/L	6439A	3	SP-3	1970.000	NC	SP-4	177.000	NC			
IRON	7439896	100	UG/L	6439A	4	SP-3	1450.000	NC	SP-4	2990.000	NC			
IRON	7439896	100	UG/L	6439A	5	SP-3	1270.000	NC	SP-4	232.000	NC	1502.378	716.012	52.34
MANGANESE	7439965	15	UG/L	6439A	1	SP-3	398.000	NC	SP-4	119.000	NC			
MANGANESE	7439965	15	UG/L	6439A	2	SP-3	512.000	NC	SP-4	113.000	NC			
MANGANESE	7439965	15	UG/L	6439A	3	SP-3	629.000	NC	SP-4	100.000	NC			
MANGANESE	7439965	15	UG/L	6439A	4	SP-3	602.000	NC	SP-4	715.000	NC			
MANGANESE	7439965	15	UG/L	6439A	5	SP-3	720.000	NC	SP-4	181.000	NC	575.649	246.123	57.24
NITRATE/NITRITE	C005	0.01	MG/L	6439A	1	SP-3	99.600	NC	SP-4	93.000	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439A	2	SP-3	77.400	NC	SP-4	85.200	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439A	3	SP-3	60.700	NC	SP-4	68.500	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439A	4	SP-3	91.000	NC	SP-4	66.100	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439A	5	SP-3	100.000	NC	SP-4	95.900	NC	86.200	82.000	4.87
SELENIUM	7782492	5	UG/L	6439A	1	SP-3	20.000	ND	SP-4	2.000	ND			
SELENIUM	7782492	5	UG/L	6439A	2	SP-3	20.000	ND	SP-4	20.000	ND			
SELENIUM	7782492	5	UG/L	6439A	3	SP-3	20.000	ND	SP-4	3.900	NC			
SELENIUM	7782492	5	UG/L	6439A	4	SP-3	20.000	ND	SP-4	7.500	NC			
SELENIUM	7782492	5	UG/L	6439A	5	SP-3	3.400	NC	SP-4	2.000	ND	16.680	7.207	56.79
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439A	1	SP-3	23.000	NC	SP-4	0.750	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439A	2	SP-3	30.000	NC	SP-4	1.500	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439A	3	SP-3	24.000	NC	SP-4	1.500	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439A	4	SP-3	25.000	NC	SP-4	39.000	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439A	5	SP-3	26.000	NC	SP-4	6.000	NC	25.624	11.388	55.56
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439A	1	SP-3	24.300	NC	SP-4	3.860	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439A	2	SP-3	58.500	NC	SP-4	11.700	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439A	3	SP-3	65.900	NC	SP-4	24.400	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439A	4	SP-3	82.400	NC	SP-4	33.000	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439A	5	SP-3	38.300	NC	SP-4	6.610	NC	55.625	17.711	68.16
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439A	1	SP-3	6.560	NC	SP-4	7.240	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439A	2	SP-3	6.670	NC	SP-4	5.990	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439A	3	SP-3	6.790	NC	SP-4	6.670	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439A	4	SP-3	7.240	NC	SP-4	7.580	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439A	5	SP-3	6.790	NC	SP-4	6.670	NC	6.811	6.836	-0.36
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439A	1	SP-3	18.100	NC	SP-4	7.950	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439A	2	SP-3	7.320	NC	SP-4	10.200	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439A	3	SP-3	7.380	NC	SP-4	10.100	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439A	4	SP-3	18.400	NC	SP-4	18.600	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=1
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439A	5	SP-3	8.580	NC	SP-4	8.450	NC	12.205	11.132	8.79
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439A	1	SP-3	363.000	NC	SP-4	86.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439A	2	SP-3	730.000	NC	SP-4	118.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439A	3	SP-3	1030.000	NC	SP-4	110.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439A	4	SP-3	180.000	NC	SP-4	1010.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439A	5	SP-3	440.000	NC	SP-4	84.000	NC	581.740	272.634	53.13
ZINC	7440666	20	UG/L	6439A	1	SP-3	365.000	NC	SP-4	69.900	NC			
ZINC	7440666	20	UG/L	6439A	2	SP-3	605.000	NC	SP-4	88.300	NC			
ZINC	7440666	20	UG/L	6439A	3	SP-3	781.000	NC	SP-4	78.100	NC			
ZINC	7440666	20	UG/L	6439A	4	SP-3	463.000	NC	SP-4	904.000	NC			
ZINC	7440666	20	UG/L	6439A	5	SP-3	550.000	NC	SP-4	101.000	NC	557.483	239.410	57.06

Subcategory=Recirculating -- Option=3

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
AEROMONAS	C2101	1	/100M	6439B	1	SP-8	28000.000	NC						
AEROMONAS	C2101	1	/100M	6439B	2	SP-8	200000.000	RC						
AEROMONAS	C2101	1	/100M	6439B	3	SP-8	27600.000	NC						
AEROMONAS	C2101	1	/100M	6439B	4	SP-8	44100.000	NC						
AEROMONAS	C2101	1	/100M	6439B	5	SP-8	28000.000	NC				65215.769		
ALUMINUM	7429905	200	UG/L	6439B	1	SP-8	71.300	NC	SP9+11	49.850	NC			
ALUMINUM	7429905	200	UG/L	6439B	2	SP-8	61.200	NC	SP9+11	17.000	ND			
ALUMINUM	7429905	200	UG/L	6439B	3	SP-8	17.000	ND	SP9+11	17.000	ND			
ALUMINUM	7429905	200	UG/L	6439B	4	SP-8	47.100	NC	SP9+11	38.100	NC			
ALUMINUM	7429905	200	UG/L	6439B	5	SP-8	109.000	NC	SP9+11	61.700	NC	61.942	37.031	40.22
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439B	1	SP-8	2.200	NC	SP9+11	1.805	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439B	2	SP-8	3.280	NC	SP9+11	3.230	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439B	3	SP-8	2.590	NC	SP9+11	1.980	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439B	4	SP-8	1.190	NC	SP9+11	1.075	NC			
AMMONIA AS NITROGEN	7664417	0.01	MG/L	6439B	5	SP-8	1.020	NC	SP9+11	0.965	NC	2.121	1.853	12.61
BARIUM	7440393	200	UG/L	6439B	1	SP-8	34.200	NC	SP9+11	33.250	NC			
BARIUM	7440393	200	UG/L	6439B	2	SP-8	35.400	NC	SP9+11	33.050	NC			
BARIUM	7440393	200	UG/L	6439B	3	SP-8	35.900	NC	SP9+11	34.950	NC			
BARIUM	7440393	200	UG/L	6439B	4	SP-8	35.100	NC	SP9+11	34.000	NC			
BARIUM	7440393	200	UG/L	6439B	5	SP-8	37.900	NC	SP9+11	34.850	NC	35.705	34.022	4.71
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439B	1	SP-8	73.000	NC	SP9+11	52.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439B	2	SP-8	38.000	NC	SP9+11	42.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439B	3	SP-8	56.000	NC	SP9+11	45.000	NC			

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=3
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439B	4	SP-8	48.000	NC	SP9+11	46.000	NC			
BIOCHEMICAL OXYGEN DEMAND	C003	2	MG/L	6439B	5	SP-8	58.000	NC	SP9+11	44.000	NC	54.941	45.827	16.59
BORON	7440428	100	UG/L	6439B	1	SP-8	208.000	NC	SP9+11	216.500	NC			
BORON	7440428	100	UG/L	6439B	2	SP-8	258.000	NC	SP9+11	265.500	NC			
BORON	7440428	100	UG/L	6439B	3	SP-8	275.000	NC	SP9+11	228.500	NC			
BORON	7440428	100	UG/L	6439B	4	SP-8	228.000	NC	SP9+11	243.000	NC			
BORON	7440428	100	UG/L	6439B	5	SP-8	442.000	NC	SP9+11	246.500	NC	283.809	240.145	15.39
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439B	1	SP-8	100.000	NC	SP9+11	95.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439B	2	SP-8	147.000	NC	SP9+11	127.000	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439B	3	SP-8	227.000	NC	SP9+11	189.500	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439B	4	SP-8	85.000	NC	SP9+11	86.500	NC			
CHEMICAL OXYGEN DEMAND (COD	C004	3	MG/L	6439B	5	SP-8	58.000	NC	SP9+11	94.500	NC	126.657	119.347	5.77
COPPER	7440508	25	UG/L	6439B	1	SP-8	20.000	NC	SP9+11	15.800	NC			
COPPER	7440508	25	UG/L	6439B	2	SP-8	16.900	NC	SP9+11	16.750	NC			
COPPER	7440508	25	UG/L	6439B	3	SP-8	19.100	NC	SP9+11	17.000	NC			
COPPER	7440508	25	UG/L	6439B	4	SP-8	18.600	NC	SP9+11	17.800	NC			
COPPER	7440508	25	UG/L	6439B	5	SP-8	20.700	NC	SP9+11	16.600	NC	19.072	16.793	11.95
FECAL STREPTOCOCCUS	C2107	1	/100M	6439B	1	SP-8	46000.000	NC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439B	2	SP-8	200000.000	RC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439B	3	SP-8	200000.000	RC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439B	4	SP-8	40000.000	NC						
FECAL STREPTOCOCCUS	C2107	1	/100M	6439B	5	SP-8	200000.000	RC				154354.324		
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439B	0	SP-8	15.000	NC	SP9+11	5.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439B	1	SP-8	6.000	ND	SP9+11	6.000	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439B	2	SP-8	6.000	ND	SP9+11	6.500	NC			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439B	3	SP-8	7.000	NC	SP9+11	5.750	ND			
HEXANE EXTRACTABLE MATERIAL	C036	5	MG/L	6439B	4	SP-8	15.000	NC	SP9+11	9.000	NC	10.091	6.491	35.67
HEXANOIC ACID	142621	10	UG/L	6439B	1	SP-8	10.000	ND	SP9+11	10.000	ND			
HEXANOIC ACID	142621	10	UG/L	6439B	3	SP-8	10.000	ND	SP9+11	10.000	ND	10.000	10.000	0.00
IRON	7439896	100	UG/L	6439B	1	SP-8	152.000	NC	SP9+11	122.500	NC			
IRON	7439896	100	UG/L	6439B	2	SP-8	136.000	NC	SP9+11	119.000	NC			
IRON	7439896	100	UG/L	6439B	3	SP-8	161.000	NC	SP9+11	114.000	NC			
IRON	7439896	100	UG/L	6439B	4	SP-8	123.000	NC	SP9+11	12.000	ND			
IRON	7439896	100	UG/L	6439B	5	SP-8	12.000	ND	SP9+11	12.000	ND	117.010	75.916	35.12
MANGANESE	7439965	15	UG/L	6439B	1	SP-8	108.000	NC	SP9+11	104.500	NC			
MANGANESE	7439965	15	UG/L	6439B	2	SP-8	123.000	NC	SP9+11	104.400	NC			
MANGANESE	7439965	15	UG/L	6439B	3	SP-8	110.000	NC	SP9+11	104.000	NC			
MANGANESE	7439965	15	UG/L	6439B	4	SP-8	142.000	NC	SP9+11	147.500	NC			
MANGANESE	7439965	15	UG/L	6439B	5	SP-8	158.000	NC	SP9+11	134.500	NC	128.529	119.285	7.19

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=3
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
NITRATE/NITRITE	C005	0.01	MG/L	6439B	1	SP-8	54.100	NC	SP9+11	108.500	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439B	2	SP-8	101.000	NC	SP9+11	102.400	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439B	3	SP-8	71.200	NC	SP9+11	89.500	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439B	4	SP-8	61.500	NC	SP9+11	113.500	NC			
NITRATE/NITRITE	C005	0.01	MG/L	6439B	5	SP-8	98.700	NC	SP9+11	115.000	NC	77.914	105.901	-35.92
SELENIUM	7782492	5	UG/L	6439B	1	SP-8	2.000	ND	SP9+11	11.350	NC			
SELENIUM	7782492	5	UG/L	6439B	2	SP-8	2.000	ND	SP9+11	3.300	NC			
SELENIUM	7782492	5	UG/L	6439B	3	SP-8	2.000	ND	SP9+11	2.000	ND			
SELENIUM	7782492	5	UG/L	6439B	4	SP-8	2.000	ND	SP9+11	11.000	ND			
SELENIUM	7782492	5	UG/L	6439B	5	SP-8	2.000	ND	SP9+11	2.550	NC	2.000	6.371	-218.56
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439B	1	SP-8	0.800	NC	SP9+11	0.100	ND			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439B	2	SP-8	0.500	NC	SP9+11	0.100	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439B	3	SP-8	0.900	NC	SP9+11	0.150	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439B	4	SP-8	0.100	ND	SP9+11	0.350	NC			
SETTLEABLE SOLIDS	N/A	0.1	mL/L	6439B	5	SP-8	0.900	NC	SP9+11	0.100	ND	0.648	0.168	74.07
TOTAL COLIFORM	E10606	1	/100M	6439B	1	SP-8	55000.000	NC						
TOTAL COLIFORM	E10606	1	/100M	6439B	2	SP-8	200000.000	RC						
TOTAL COLIFORM	E10606	1	/100M	6439B	3	SP-8	200000.000	RC						
TOTAL COLIFORM	E10606	1	/100M	6439B	4	SP-8	200000.000	RC						
TOTAL COLIFORM	E10606	1	/100M	6439B	5	SP-8	101000.000	NC				159608.055		
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439B	1	SP-8	7.800	NC	SP9+11	3.610	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439B	2	SP-8	82.800	NC	SP9+11	5.625	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439B	3	SP-8	8.470	NC	SP9+11	5.795	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439B	4	SP-8	6.530	NC	SP9+11	2.600	NC			
TOTAL KJELDAHL NITROGEN	C021	0.5	MG/L	6439B	5	SP-8	6.220	NC	SP9+11	3.950	NC	21.475	4.371	79.65
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439B	1	SP-8	8.150	NC	SP9+11	8.490	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439B	2	SP-8	9.520	NC	SP9+11	14.500	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439B	3	SP-8	7.580	NC	SP9+11	8.095	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439B	4	SP-8	8.490	NC	SP9+11	8.035	NC			
TOTAL ORTHOPHOSPHATE	C034	0.01	MG/L	6439B	5	SP-8	8.040	NC	SP9+11	7.980	NC	8.362	9.455	-13.07
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439B	1	SP-8	8.960	NC	SP9+11	8.515	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439B	2	SP-8	10.700	NC	SP9+11	17.500	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439B	3	SP-8	12.700	NC	SP9+11	10.850	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439B	4	SP-8	8.710	NC	SP9+11	9.145	NC			
TOTAL PHOSPHORUS	14265442	0.01	MG/L	6439B	5	SP-8	8.960	NC	SP9+11	8.265	NC	10.028	10.918	-8.87
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439B	1	SP-8	56.000	NC	SP9+11	44.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439B	2	SP-8	58.000	NC	SP9+11	53.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439B	3	SP-8	68.000	NC	SP9+11	61.000	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439B	4	SP-8	30.000	NC	SP9+11	28.500	NC			
TOTAL SUSPENDED SOLIDS	C009	4	MG/L	6439B	5	SP-8	74.000	NC	SP9+11	46.500	NC	58.268	47.093	19.18

Appendix C: Daily Influent and Effluent Data for Pollutants of Concern

Subcategory=Recirculating -- Option=3
(continued)

Analyte	CAS_No	Baseline Value	Unit	Episode	Sample Day	Influent SamPoint	Influent Conc.	Inf. Censor	Effluent SamPoint	Effluent Conc.	Eff. Censor	Influent LTA	Effluent LTA	Percent Removal
ZINC	7440666	20	UG/L	6439B	1	SP-8	60.800	NC	SP9+11	50.050	NC			
ZINC	7440666	20	UG/L	6439B	2	SP-8	71.800	NC	SP9+11	70.050	NC			
ZINC	7440666	20	UG/L	6439B	3	SP-8	70.200	NC	SP9+11	68.050	NC			
ZINC	7440666	20	UG/L	6439B	4	SP-8	57.500	NC	SP9+11	1.000	ND			
ZINC	7440666	20	UG/L	6439B	5	SP-8	79.700	NC	SP9+11	1.000	ND	68.120	38.265	43.83

APPENDIX D
SUMMARY STATISTICS AT EACH SAMPLE POINT FOR POLLUTANTS OF CONCERN

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
AEROMONAS	6460	SP7,SP8	100000.00	1	1		100000.00					100000.00	100000.00	/100M
AEROMONAS	6460	SP7,SP9	1000.00	1	1		1000.00					1000.00	1000.00	/100M
AEROMONAS	6460	SP-8	100000.00	1	1		100000.00					100000.00	100000.00	/100M
AEROMONAS	6460	SP-9	1000.00	1	1		1000.00					1000.00	1000.00	/100M
AEROMONAS	6460	SP10+11	507.31	4	0	217.09	491.63	491.63	217.09	270.00	690.00			/100M
ALUMINUM	6297	SP2+3	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
ALUMINUM	6297	SP-4	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
ALUMINUM	6297	SP5+6	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
ALUMINUM	6297	SP-7	796.45	5	0	297.07	764.00	764.00	297.07	300.00	1090.00			UG/L
ALUMINUM	6297	SP8+9	50.84	5	4	1.88	50.84	54.20		54.20	54.20	50.00	50.00	UG/L
ALUMINUM	6297	SP8+9,SP5+6	50.01	5	4	0.02	50.01	50.04		50.04	50.04	50.00	50.00	UG/L
ALUMINUM	6297	SP-10	534.55	5	0	130.41	530.60	530.60	130.41	357.00	683.00			UG/L
ALUMINUM	6297	SP-11	55.08	5	4	11.36	55.08	75.40		75.40	75.40	50.00	50.00	UG/L
ALUMINUM	6297	SP11,SP5+6	50.05	5	5	0.11	50.05					50.00	50.25	UG/L
ALUMINUM	6297	SP-12	2205.66	5	0	854.94	2086.00	2086.00	854.94	720.00	2950.00			UG/L
ALUMINUM	6297	SP13+14	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
ALUMINUM	6297	SP13+14,SP2+3	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
ALUMINUM	6460	SP-7	48.00	5	5	0.00	48.00					48.00	48.00	UG/L
ALUMINUM	6460	SP7,SP8	505.87	5	4	1023.83	505.87	2337.34		2337.34	2337.34	48.00	48.00	UG/L
ALUMINUM	6460	SP7,SP9	51.16	5	4	7.06	51.16	63.79		63.79	63.79	48.00	48.00	UG/L
ALUMINUM	6460	SP-8	2860.00	1	0		2860.00	2860.00		2860.00	2860.00			UG/L
ALUMINUM	6460	SP-9	67.40	1	0		67.40	67.40		67.40	67.40			UG/L
ALUMINUM	6460	SP10+11	48.00	5	5	0.00	48.00					48.00	48.00	UG/L
AMMONIA AS NITROGEN	6297	SP2+3	0.12	5	0	0.02	0.12	0.12	0.02	0.10	0.14			MG/L
AMMONIA AS NITROGEN	6297	SP-4	0.05	5	5	0.00	0.05					0.05	0.05	MG/L
AMMONIA AS NITROGEN	6297	SP5+6	0.46	5	0	0.21	0.46	0.46	0.21	0.34	0.84			MG/L
AMMONIA AS NITROGEN	6297	SP-7	1.48	5	0	0.80	1.46	1.46	0.80	0.90	2.85			MG/L
AMMONIA AS NITROGEN	6297	SP8+9	2.85	5	0	0.56	2.84	2.84	0.56	2.04	3.53			MG/L
AMMONIA AS NITROGEN	6297	SP8+9,SP5+6	0.49	5	0	0.21	0.48	0.48	0.21	0.36	0.86			MG/L
AMMONIA AS NITROGEN	6297	SP-10	1.05	5	0	0.44	1.00	1.00	0.44	0.37	1.46			MG/L
AMMONIA AS NITROGEN	6297	SP-11	1.20	5	0	0.50	1.14	1.14	0.50	0.40	1.68			MG/L
AMMONIA AS NITROGEN	6297	SP11,SP5+6	0.47	5	0	0.21	0.47	0.47	0.21	0.35	0.85			MG/L
AMMONIA AS NITROGEN	6297	SP-12	2.08	5	0	1.23	2.05	2.05	1.23	1.16	4.20			MG/L
AMMONIA AS NITROGEN	6297	SP13+14	1.31	5	0	0.35	1.30	1.30	0.35	0.84	1.69			MG/L
AMMONIA AS NITROGEN	6297	SP13+14,SP2+3	0.13	5	0	0.02	0.13	0.13	0.02	0.11	0.16			MG/L
AMMONIA AS NITROGEN	6460	SP-7	0.15	5	0	0.05	0.14	0.14	0.05	0.10	0.22			MG/L
AMMONIA AS NITROGEN	6460	SP7,SP8	2.45	5	0	5.04	2.40	2.40	5.04	0.10	11.42			MG/L
AMMONIA AS NITROGEN	6460	SP7,SP9	0.19	5	0	0.09	0.18	0.18	0.09	0.10	0.32			MG/L
AMMONIA AS NITROGEN	6460	SP-8	14.00	1	0		14.00	14.00		14.00	14.00			MG/L
AMMONIA AS NITROGEN	6460	SP-9	0.36	1	0		0.36	0.36		0.36	0.36			MG/L
AMMONIA AS NITROGEN	6460	SP10+11	0.15	5	0	0.06	0.14	0.14	0.06	0.07	0.22			MG/L
BARIUM	6297	SP2+3	21.82	5	0	0.48	21.82	21.82	0.48	21.50	22.65			UG/L
BARIUM	6297	SP-4	21.72	5	0	0.41	21.72	21.72	0.41	21.20	22.20			UG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru (continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
BARIUM	6297	SP5+6	21.78	5	0	0.23	21.78	21.78	0.23	21.50	22.00			UG/L
BARIUM	6297	SP-7	491.71	5	0	430.97	416.98	416.98	430.97	66.90	1060.00			UG/L
BARIUM	6297	SP8+9	45.01	5	0	1.36	45.01	45.01	1.36	43.50	47.00			UG/L
BARIUM	6297	SP8+9,SP5+6	22.01	5	0	0.24	22.01	22.01	0.24	21.72	22.25			UG/L
BARIUM	6297	SP-10	158.37	5	0	57.72	155.82	155.82	57.72	88.10	227.00			UG/L
BARIUM	6297	SP-11	44.36	5	0	1.05	44.36	44.36	1.05	43.30	45.70			UG/L
BARIUM	6297	SP11,SP5+6	22.00	5	0	0.22	22.00	22.00	0.22	21.74	22.23			UG/L
BARIUM	6297	SP-12	313.40	5	0	49.23	312.60	312.60	49.23	249.00	382.00			UG/L
BARIUM	6297	SP13+14	23.04	5	0	0.33	23.04	23.04	0.33	22.60	23.50			UG/L
BARIUM	6297	SP13+14,SP2+3	21.83	5	0	0.47	21.83	21.83	0.47	21.52	22.65			UG/L
BARIUM	6460	SP-7	19.47	5	0	2.45	19.44	19.44	2.45	17.10	22.20			UG/L
BARIUM	6460	SP7,SP8	101.10	5	0	198.35	108.52	108.52	198.35	17.10	463.31			UG/L
BARIUM	6460	SP7,SP9	19.92	5	0	2.30	19.90	19.90	2.30	17.10	22.20			UG/L
BARIUM	6460	SP-8	565.00	1	0		565.00	565.00		565.00	565.00			UG/L
BARIUM	6460	SP-9	20.70	1	0		20.70	20.70		20.70	20.70			UG/L
BARIUM	6460	SP10+11	20.76	5	0	2.37	20.73	20.73	2.37	17.30	22.60			UG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP2+3	3.94	5	3	1.44	3.93	2.63	0.60	2.20	3.05	4.00	6.00	MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP-4	4.40	5	5	0.89	4.40					4.00	6.00	MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP5+6	4.30	5	3	1.02	4.29	3.73	0.67	3.25	4.20	4.00	6.00	MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP-7	716.29	5	0	155.29	222.96	222.96	155.29	3.78	380.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP8+9	142.07	5	0	60.49	136.30	136.30	60.49	58.00	185.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP8+9,SP5+6	5.63	5	0	1.10	5.60	5.60	1.10	3.79	6.77			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP-10	183.19	5	0	123.92	173.20	173.20	123.92	56.00	376.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP-11	116.55	5	0	59.71	113.20	113.20	59.71	56.00	183.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP11,SP5+6	5.42	5	3	1.17	5.37	4.87	1.55	3.77	5.97	4.65	6.78	MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP-12	343.43	5	0	86.21	338.00	338.00	86.21	184.00	380.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP13+14	14.53	5	0	2.04	14.49	14.49	2.04	11.20	16.55			MG/L
BIOCHEMICAL OXYGEN DEMAND	6297	SP13+14,SP2+3	4.05	5	3	1.43	4.03	2.75	0.60	2.32	3.18	4.10	6.10	MG/L
BIOCHEMICAL OXYGEN DEMAND	6460	SP-7	2.80	5	5	1.79	2.80					2.00	6.00	MG/L
BIOCHEMICAL OXYGEN DEMAND	6460	SP7,SP8	652.15	5	4	1451.55	652.15	3248.76		3248.76	3248.76	2.00	6.00	MG/L
BIOCHEMICAL OXYGEN DEMAND	6460	SP7,SP9	4.59	5	4	3.96	4.59	10.96		10.96	10.96	2.00	6.00	MG/L
BIOCHEMICAL OXYGEN DEMAND	6460	SP-8	3990.00	1	0		3990.00	3990.00		3990.00	3990.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6460	SP-9	13.00	1	0		13.00	13.00		13.00	13.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6460	SP10+11	2.00	5	5	0.00	2.00					2.00	2.00	MG/L
BORON	6297	SP2+3	48.59	5	0	2.30	48.58	48.58	2.30	45.00	51.00			UG/L
BORON	6297	SP-4	47.14	5	0	0.88	47.14	47.14	0.88	46.20	48.50			UG/L
BORON	6297	SP5+6	46.54	5	0	1.12	46.54	46.54	1.12	44.90	47.75			UG/L
BORON	6297	SP-7	404.24	5	0	398.78	332.80	332.80	398.78	57.10	955.00			UG/L
BORON	6297	SP8+9	50.84	5	0	0.51	50.84	50.84	0.51	50.30	51.60			UG/L
BORON	6297	SP8+9,SP5+6	46.59	5	0	1.10	46.58	46.58	1.10	44.96	47.78			UG/L
BORON	6297	SP-10	128.20	5	0	79.09	123.82	123.82	79.09	62.10	229.00			UG/L
BORON	6297	SP-11	50.26	5	0	0.60	50.26	50.26	0.60	49.70	51.10			UG/L
BORON	6297	SP11,SP5+6	46.58	5	0	1.11	46.58	46.58	1.11	44.95	47.77			UG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru
(continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
BORON	6297	SP-12	185.84	5	0	58.17	182.80	182.80	58.17	105.00	231.00			UG/L
BORON	6297	SP13+14	48.95	5	0	1.84	48.94	48.94	1.84	46.65	51.60			UG/L
BORON	6297	SP13+14,SP2+3	48.59	5	0	2.27	48.58	48.58	2.27	45.04	50.97			UG/L
BORON	6460	SP-7	208.51	5	3	165.40	82.98	204.45	245.44	30.90	378.00	2.00	2.00	UG/L
BORON	6460	SP7,SP8	138.15	5	2	159.10	102.03	168.72	184.26	30.90	378.00	2.00	2.00	UG/L
BORON	6460	SP7,SP9	208.51	5	3	165.40	82.98	204.45	245.44	30.90	378.00	2.00	2.00	UG/L
BORON	6460	SP-8	119.00	1	0		119.00	119.00		119.00	119.00			UG/L
BORON	6460	SP-9	2.00	1	1		2.00					2.00	2.00	UG/L
BORON	6460	SP10+11	11.08	5	3	12.81	10.61	23.53	10.01	16.45	30.60	2.00	2.00	UG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP2+3	23.10	5	3	4.53	23.06	27.65	3.46	25.20	30.10	20.00	20.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP-4	20.00	5	5	0.00	20.00					20.00	20.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP5+6	20.00	5	5	0.00	20.00					20.00	20.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP-7	1958.78	5	0	938.20	1310.40	1310.40	938.20	105.00	2060.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP8+9	442.32	5	0	113.52	440.90	440.90	113.52	372.00	642.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP8+9,SP5+6	24.17	5	0	1.12	24.17	24.17	1.12	23.49	26.16			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP-10	1823.33	5	0	783.95	1418.00	1418.00	783.95	180.00	2230.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP-11	408.14	5	0	48.37	407.60	407.60	48.37	360.00	472.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP11,SP5+6	23.83	5	5	0.48	23.83					23.36	24.46	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP-12	1896.35	5	0	1925.93	1802.40	1802.40	1925.93	480.00	5130.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP13+14	43.28	5	1	16.61	42.71	48.39	12.37	30.00	56.30	20.00	20.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6297	SP13+14,SP2+3	23.30	5	3	4.48	23.25	27.73	3.66	25.15	30.32	20.10	20.36	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6460	SP-7	10.80	5	4	1.79	10.80	14.00		14.00	14.00	10.00	10.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6460	SP7,SP8	2401928.41	5	3	3309.15	1490.89	3712.24	5230.10	14.00	7410.47	10.00	10.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6460	SP7,SP9	15.13	5	3	8.11	14.55	21.36	10.41	14.00	28.73	10.00	10.00	MG/L
CHEMICAL OXYGEN DEMAND (COD)	6460	SP-8	9100.00	1	0		9100.00	9100.00		9100.00	9100.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6460	SP-9	33.00	1	0		33.00	33.00		33.00	33.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6460	SP10+11	14.40	5	3	6.02	14.40	21.00	0.00	21.00	21.00	10.00	10.00	MG/L
COPPER	6297	SP2+3	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
COPPER	6297	SP-4	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
COPPER	6297	SP5+6	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
COPPER	6297	SP-7	117.86	5	0	28.85	116.40	116.40	28.85	68.00	139.00			UG/L
COPPER	6297	SP8+9	12.58	5	0	1.19	12.57	12.57	1.19	11.25	14.50			UG/L
COPPER	6297	SP8+9,SP5+6	5.07	5	0	0.01	5.07	5.07	0.01	5.06	5.09			UG/L
COPPER	6297	SP-10	109.82	5	0	29.32	109.12	109.12	29.32	83.50	141.00			UG/L
COPPER	6297	SP-11	13.47	5	0	2.41	13.40	13.40	2.41	9.40	15.90			UG/L
COPPER	6297	SP11,SP5+6	5.08	5	5	0.02	5.08					5.04	5.11	UG/L
COPPER	6297	SP-12	296.82	5	0	133.04	269.04	269.04	133.04	68.20	406.00			UG/L
COPPER	6297	SP13+14	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
COPPER	6297	SP13+14,SP2+3	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
COPPER	6460	SP-7	1.00	5	5	0.00	1.00					1.00	1.00	UG/L
COPPER	6460	SP7,SP8	32.10	5	4	69.54	32.10	156.50		156.50	156.50	1.00	1.00	UG/L
COPPER	6460	SP7,SP9	1.00	5	5	0.00	1.00					1.00	1.00	UG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru (continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
COPPER	6460	SP-8	192.00	1	0		192.00	192.00		192.00	192.00			UG/L
COPPER	6460	SP-9	1.00	1	1		1.00					1.00	1.00	UG/L
COPPER	6460	SP10+11	1.00	5	5	0.00	1.00					1.00	1.00	UG/L
FECAL STREPTOCOCCUS	6460	SP7,SP8	2900000.00	1	0		2900000.00	2900000.00		2900000.00	2900000.00			/100M
FECAL STREPTOCOCCUS	6460	SP7,SP9	2500.00	1	0		2500.00	2500.00		2500.00	2500.00			/100M
FECAL STREPTOCOCCUS	6460	SP-8	2900000.00	1	0		2900000.00	2900000.00		2900000.00	2900000.00			/100M
FECAL STREPTOCOCCUS	6460	SP-9	2500.00	1	0		2500.00	2500.00		2500.00	2500.00			/100M
FECAL STREPTOCOCCUS	6460	SP10+11	390.35	4	0	267.03	360.25	360.25	267.03	120.00	730.00			/100M
HEXANE EXTRACTABLE MATERIAL	6297	SP2+3	7.79	5	3	4.34	7.29	10.46	6.46	5.89	15.03	5.00	5.51	MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP-4	7.35	5	3	3.49	7.15	10.16	4.28	7.13	13.19	5.00	5.41	MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP5+6	10.27	5	2	8.10	9.66	12.73	9.79	6.02	23.97	5.00	5.09	MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP-7	86.76	5	0	69.92	81.05	81.05	69.92	20.50	200.89			MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP8+9	70.88	5	0	38.17	49.19	49.19	38.17	5.00	85.35			MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP8+9,SP5+6	10.17	5	0	8.27	10.05	10.05	8.27	5.06	24.57			MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP-10	87.40	5	1	69.91	79.94	98.68	64.63	30.63	186.27	5.00	5.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP-11	82.32	5	0	48.75	62.92	62.92	48.75	9.93	109.50			MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP11,SP5+6	10.73	5	2	8.33	10.18	13.56	9.79	7.00	24.81	5.08	5.14	MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP-12	501.35	4	0	288.46	485.75	485.75	288.46	247.00	900.00			MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP13+14	19.07	5	2	16.31	18.37	27.29	15.30	16.30	44.77	5.00	5.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6297	SP13+14,SP2+3	7.87	5	3	4.30	7.40	10.54	6.37	6.04	15.04	5.00	5.90	MG/L
HEXANE EXTRACTABLE MATERIAL	6460	SP-7	5.90	5	5	0.22	5.90					5.50	6.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6460	SP7,SP8	124.60	5	4	265.48	124.60	599.50		599.50	599.50	5.50	6.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6460	SP7,SP9	5.90	5	5	0.22	5.90					5.50	6.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6460	SP-8	735.00	1	0		735.00	735.00		735.00	735.00			MG/L
HEXANE EXTRACTABLE MATERIAL	6460	SP-9	6.00	1	1		6.00					6.00	6.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6460	SP10+11	5.55	5	5	0.45	5.55					5.00	6.00	MG/L
HEXANOIC ACID	6297	SP2+3	10.00	3	3	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6297	SP-4	10.00	3	3	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6297	SP5+6	10.00	3	3	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6297	SP-7	71.91	3	0	34.05	69.80	69.80	34.05	47.60	109.00			UG/L
HEXANOIC ACID	6297	SP8+9	112.29	3	0	2.35	112.28	112.28	2.35	110.85	115.00			UG/L
HEXANOIC ACID	6297	SP8+9,SP5+6	11.01	3	0	0.02	11.01	11.01	0.02	11.00	11.04			UG/L
HEXANOIC ACID	6297	SP-10	48.62	3	0	26.62	46.10	46.10	26.62	24.40	75.80			UG/L
HEXANOIC ACID	6297	SP-11	111.32	3	0	28.97	110.13	110.13	28.97	85.40	142.00			UG/L
HEXANOIC ACID	6297	SP11,SP5+6	10.99	3	3	0.29	10.99					10.74	11.30	UG/L
HEXANOIC ACID	6297	SP-12	390.64	3	0	211.47	242.87	242.87	211.47	33.10	456.00			UG/L
HEXANOIC ACID	6297	SP13+14	10.00	3	3	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6297	SP13+14,SP2+3	10.00	3	3	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6460	SP-7	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6460	SP7,SP8	398.75	2	1	549.77	398.75	787.50		787.50	787.50	10.00	10.00	UG/L
HEXANOIC ACID	6460	SP7,SP9	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6460	SP-8	965.00	1	0		965.00	965.00		965.00	965.00			UG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru (continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
HEXANOIC ACID	6460	SP-9	10.00	1	1		10.00					10.00	10.00	UG/L
HEXANOIC ACID	6460	SP10+11	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
IRON	6297	SP2+3	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
IRON	6297	SP-4	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
IRON	6297	SP5+6	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
IRON	6297	SP-7	2070.12	5	0	809.21	2003.00	2003.00	809.21	885.00	2930.00			UG/L
IRON	6297	SP8+9	223.64	5	0	9.24	223.60	223.60	9.24	210.00	231.00			UG/L
IRON	6297	SP8+9,SP5+6	51.72	5	0	0.09	51.72	51.72	0.09	51.58	51.79			UG/L
IRON	6297	SP-10	1617.39	5	0	432.80	1608.00	1608.00	432.80	1260.00	2230.00			UG/L
IRON	6297	SP-11	270.64	5	0	10.88	270.60	270.60	10.88	257.00	283.00			UG/L
IRON	6297	SP11,SP5+6	52.18	5	5	0.11	52.18					52.04	52.30	UG/L
IRON	6297	SP-12	5776.34	5	0	2021.17	5552.00	5552.00	2021.17	2230.00	7210.00			UG/L
IRON	6297	SP13+14	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
IRON	6297	SP13+14,SP2+3	50.00	5	5	0.00	50.00					50.00	50.00	UG/L
IRON	6460	SP-7	54.14	5	1	36.11	50.62	58.28	36.72	25.60	92.90	20.00	20.00	UG/L
IRON	6460	SP7,SP8	10758.37	5	0	11699.39	5290.38	5290.38	11699.39	25.60	26218.81			UG/L
IRON	6460	SP7,SP9	152.23	5	0	181.93	138.38	138.38	181.93	25.60	458.82			UG/L
IRON	6460	SP-8	32200.00	1	0		32200.00	32200.00		32200.00	32200.00			UG/L
IRON	6460	SP-9	559.00	1	0		559.00	559.00		559.00	559.00			UG/L
IRON	6460	SP10+11	76.46	5	0	34.59	73.36	73.36	34.59	34.65	105.30			UG/L
MANGANESE	6297	SP2+3	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
MANGANESE	6297	SP-4	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
MANGANESE	6297	SP5+6	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
MANGANESE	6297	SP-7	429.67	5	0	181.02	411.80	411.80	181.02	166.00	593.00			UG/L
MANGANESE	6297	SP8+9	146.74	5	0	8.77	146.70	146.70	8.77	141.00	162.00			UG/L
MANGANESE	6297	SP8+9,SP5+6	6.40	5	0	0.09	6.40	6.40	0.09	6.35	6.55			UG/L
MANGANESE	6297	SP-10	441.28	5	0	161.54	435.80	435.80	161.54	280.00	642.00			UG/L
MANGANESE	6297	SP-11	182.85	5	0	9.83	182.80	182.80	9.83	170.00	195.00			UG/L
MANGANESE	6297	SP11,SP5+6	6.76	5	5	0.10	6.76					6.63	6.88	UG/L
MANGANESE	6297	SP-12	1168.25	5	0	482.28	1125.00	1125.00	482.28	463.00	1740.00			UG/L
MANGANESE	6297	SP13+14	9.29	5	0	0.61	9.29	9.29	0.61	8.65	9.90			UG/L
MANGANESE	6297	SP13+14,SP2+3	5.04	5	5	0.01	5.04					5.04	5.05	UG/L
MANGANESE	6460	SP-7	11.55	5	0	6.61	11.16	11.16	6.61	5.50	18.50			UG/L
MANGANESE	6460	SP7,SP8	988.02	5	0	1447.57	659.94	659.94	1447.57	6.00	3249.41			UG/L
MANGANESE	6460	SP7,SP9	18.03	5	0	11.39	16.96	16.96	11.39	6.00	34.48			UG/L
MANGANESE	6460	SP-8	3990.00	1	0		3990.00	3990.00		3990.00	3990.00			UG/L
MANGANESE	6460	SP-9	41.10	1	0		41.10	41.10		41.10	41.10			UG/L
MANGANESE	6460	SP10+11	12.79	5	0	5.08	12.42	12.42	5.08	6.15	17.50			UG/L
NITRATE/NITRITE	6297	SP2+3	1.02	5	0	0.07	1.02	1.02	0.07	0.94	1.11			MG/L
NITRATE/NITRITE	6297	SP-4	1.08	5	0	0.03	1.08	1.08	0.03	1.04	1.12			MG/L
NITRATE/NITRITE	6297	SP5+6	1.03	5	0	0.05	1.03	1.03	0.05	0.97	1.09			MG/L
NITRATE/NITRITE	6297	SP-7	0.87	5	0	0.23	0.87	0.87	0.23	0.72	1.26			MG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru
(continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
NITRATE/NITRITE	6297	SP8+9	0.35	5	5	0.14	0.35					0.25	0.50	MG/L
NITRATE/NITRITE	6297	SP8+9,SP5+6	1.02	5	5	0.05	1.02					0.96	1.08	MG/L
NITRATE/NITRITE	6297	SP-10	0.82	5	0	0.15	0.82	0.82	0.15	0.72	1.09			MG/L
NITRATE/NITRITE	6297	SP-11	0.64	5	4	0.74	0.64	1.94		1.94	1.94	0.25	0.50	MG/L
NITRATE/NITRITE	6297	SP11,SP5+6	1.03	5	0	0.04	1.03	1.03	0.04	0.98	1.08			MG/L
NITRATE/NITRITE	6297	SP-12	0.86	5	0	0.09	0.86	0.86	0.09	0.74	0.96			MG/L
NITRATE/NITRITE	6297	SP13+14	0.25	5	5	0.00	0.25					0.25	0.25	MG/L
NITRATE/NITRITE	6297	SP13+14,SP2+3	1.01	5	0	0.07	1.01	1.01	0.07	0.93	1.10			MG/L
NITRATE/NITRITE	6460	SP-7	0.42	5	0	0.29	0.39	0.39	0.29	0.14	0.75			MG/L
NITRATE/NITRITE	6460	SP7,SP8	0.49	5	0	0.28	0.44	0.44	0.28	0.14	0.75			MG/L
NITRATE/NITRITE	6460	SP7,SP9	0.40	5	0	0.31	0.37	0.37	0.31	0.12	0.75			MG/L
NITRATE/NITRITE	6460	SP-8	0.55	1	0		0.55	0.55		0.55	0.55			MG/L
NITRATE/NITRITE	6460	SP-9	0.09	1	0		0.09	0.09		0.09	0.09			MG/L
NITRATE/NITRITE	6460	SP10+11	0.41	5	0	0.29	0.38	0.38	0.29	0.15	0.71			MG/L
SELENIUM	6297	SP2+3	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6297	SP-4	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6297	SP5+6	2.08	5	4	0.18	2.08	2.40		2.40	2.40	2.00	2.00	UG/L
SELENIUM	6297	SP-7	3.51	5	1	1.18	3.47	3.84	0.97	2.50	4.60	2.00	2.00	UG/L
SELENIUM	6297	SP8+9	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6297	SP8+9,SP5+6	2.08	5	5	0.18	2.08					2.00	2.40	UG/L
SELENIUM	6297	SP-10	2.28	5	3	0.53	2.26	2.65	0.78	2.10	3.20	2.00	2.00	UG/L
SELENIUM	6297	SP-11	2.40	5	4	0.89	2.40	4.00		4.00	4.00	2.00	2.00	UG/L
SELENIUM	6297	SP11,SP5+6	2.08	5	4	0.19	2.08	2.42		2.42	2.42	2.00	2.00	UG/L
SELENIUM	6297	SP-12	12.09	5	0	10.35	12.06	12.06	10.35	6.20	30.50			UG/L
SELENIUM	6297	SP13+14	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6297	SP13+14,SP2+3	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6460	SP-7	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6460	SP7,SP8	3.47	5	4	3.28	3.47	9.33		9.33	9.33	2.00	2.00	UG/L
SELENIUM	6460	SP7,SP9	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6460	SP-8	11.00	1	0		11.00	11.00		11.00	11.00			UG/L
SELENIUM	6460	SP-9	2.00	1	1		2.00					2.00	2.00	UG/L
SELENIUM	6460	SP10+11	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SETTLEABLE SOLIDS	6297	SP-7	71.79	4	0	24.10	71.00	71.00	24.10	50.00	105.00			mL/L
SETTLEABLE SOLIDS	6297	SP8+9	0.28	5	4	0.40	0.28	1.00		1.00	1.00	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6297	SP8+9,SP5+6	0.28	5	4	0.40	0.28	1.00		1.00	1.00	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6297	SP-10	41.75	4	0	20.68	40.50	40.50	20.68	21.00	69.00			mL/L
SETTLEABLE SOLIDS	6297	SP-11	0.70	5	3	0.84	0.66	1.50	0.71	1.00	2.00	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6297	SP11,SP5+6	0.70	5	3	0.84	0.66	1.50	0.71	1.00	2.00	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6297	SP-12	96.50	2	0	2.12	96.50	96.50	2.12	95.00	98.00			mL/L
SETTLEABLE SOLIDS	6297	SP13+14	0.55	4	2	0.52	0.55	1.00	0.00	1.00	1.00	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6297	SP13+14,SP2+3	0.55	4	2	0.52	0.55	1.00	0.00	1.00	1.00	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6460	SP7,SP8	240.00	1	0		240.00	240.00		240.00	240.00			mL/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru (continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
SETTLEABLE SOLIDS	6460	SP7,SP9	0.20	1	0		0.20	0.20		0.20	0.20			mL/L
SETTLEABLE SOLIDS	6460	SP-8	240.00	1	0		240.00	240.00		240.00	240.00			mL/L
SETTLEABLE SOLIDS	6460	SP-9	0.20	1	0		0.20	0.20		0.20	0.20			mL/L
SETTLEABLE SOLIDS	DMR1	SP-1	0.10	19	19	0.00	0.10					0.10	0.10	mL/L
SETTLEABLE SOLIDS	DMR2	SP-1	0.10	18	18	0.00	0.10					0.10	0.10	mL/L
SETTLEABLE SOLIDS	DMR3	SP-1	0.10	37	37	0.00	0.10					0.10	0.10	mL/L
SETTLEABLE SOLIDS	DMR4	SP-1	0.10	35	35	0.00	0.10					0.10	0.10	mL/L
TOTAL COLIFORM	6460	SP7,SP8	10900.00	1	0		10900.00	10900.00		10900.00	10900.00			/100M
TOTAL COLIFORM	6460	SP7,SP9	460.00	1	0		460.00	460.00		460.00	460.00			/100M
TOTAL COLIFORM	6460	SP-8	10900.00	1	0		10900.00	10900.00		10900.00	10900.00			/100M
TOTAL COLIFORM	6460	SP-9	460.00	1	0		460.00	460.00		460.00	460.00			/100M
TOTAL COLIFORM	6460	SP10+11	321.68	4	1	254.43	279.25	372.00	213.28	126.00	505.00	1.00	1.00	/100M
TOTAL KJELDAHL NITROGEN	6297	SP2+3	0.50	5	5	0.00	0.50					0.50	0.50	MG/L
TOTAL KJELDAHL NITROGEN	6297	SP-4	0.50	5	5	0.00	0.50					0.50	0.50	MG/L
TOTAL KJELDAHL NITROGEN	6297	SP5+6	1.78	5	0	2.69	1.85	1.85	2.69	0.60	6.67			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP-7	71.44	5	0	49.20	63.08	63.08	49.20	12.50	142.00			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP8+9	13.77	5	0	0.75	13.77	13.77	0.75	13.10	14.90			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP8+9,SP5+6	1.91	5	0	2.66	1.97	1.97	2.66	0.73	6.73			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP-10	51.40	5	0	36.69	46.18	46.18	36.69	13.20	98.60			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP-11	18.26	5	0	5.81	11.08	11.08	5.81	0.70	14.00			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP11,SP5+6	1.88	5	0	2.68	1.94	1.94	2.68	0.67	6.74			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP-12	65.89	5	0	35.86	47.19	47.19	35.86	4.23	96.70			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP13+14	28.03	5	0	57.44	30.25	30.25	57.44	4.11	133.00			MG/L
TOTAL KJELDAHL NITROGEN	6297	SP13+14,SP2+3	0.79	5	5	0.57	0.79					0.54	1.81	MG/L
TOTAL KJELDAHL NITROGEN	6460	SP-7	0.27	5	0	0.05	0.27	0.27	0.05	0.22	0.33			MG/L
TOTAL KJELDAHL NITROGEN	6460	SP7,SP8	13.56	5	0	24.80	11.37	11.37	24.80	0.22	55.73			MG/L
TOTAL KJELDAHL NITROGEN	6460	SP7,SP9	0.54	5	0	0.59	0.54	0.54	0.59	0.22	1.59			MG/L
TOTAL KJELDAHL NITROGEN	6460	SP-8	68.40	1	0		68.40	68.40		68.40	68.40			MG/L
TOTAL KJELDAHL NITROGEN	6460	SP-9	1.90	1	0		1.90	1.90		1.90	1.90			MG/L
TOTAL KJELDAHL NITROGEN	6460	SP10+11	0.28	5	0	0.06	0.27	0.27	0.06	0.19	0.35			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP2+3	0.13	5	1	0.07	0.13	0.14	0.06	0.09	0.21	0.05	0.05	MG/L
TOTAL ORTHOPHOSPHATE	6297	SP-4	0.11	5	3	0.08	0.11	0.20	0.01	0.19	0.21	0.05	0.05	MG/L
TOTAL ORTHOPHOSPHATE	6297	SP5+6	0.18	5	0	0.09	0.17	0.17	0.09	0.08	0.32			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP-7	9.94	5	0	4.28	9.86	9.86	4.28	6.38	17.30			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP8+9	11.04	5	0	0.70	11.04	11.04	0.70	10.15	12.10			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP8+9,SP5+6	0.28	5	0	0.09	0.28	0.28	0.09	0.18	0.42			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP-10	7.52	5	0	3.37	7.24	7.24	3.37	3.15	11.00			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP-11	10.74	5	0	0.79	10.74	10.74	0.79	9.68	11.50			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP11,SP5+6	0.28	5	0	0.09	0.28	0.28	0.09	0.20	0.42			MG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru
(continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
TOTAL ORTHOPHOSPHATE	6297	SP-12	15.84	5	0	8.21	14.60	14.60	8.21	4.30	24.60			MG/L
TOTAL ORTHOPHOSPHATE	6297	SP13+14	0.32	5	1	0.19	0.31	0.38	0.14	0.18	0.51	0.05	0.05	MG/L
TOTAL ORTHOPHOSPHATE	6297	SP13+14,SP2+3	0.13	5	1	0.07	0.13	0.15	0.06	0.09	0.21	0.05	0.05	MG/L
TOTAL ORTHOPHOSPHATE	6460	SP-7	0.02	5	0	0.01	0.02	0.02	0.01	0.01	0.03			MG/L
TOTAL ORTHOPHOSPHATE	6460	SP7,SP8	16.67	5	0	12.12	5.44	5.44	12.12	0.01	27.11			MG/L
TOTAL ORTHOPHOSPHATE	6460	SP7,SP9	0.08	5	0	0.13	0.08	0.08	0.13	0.01	0.30			MG/L
TOTAL ORTHOPHOSPHATE	6460	SP-8	33.30	1	0		33.30	33.30		33.30	33.30			MG/L
TOTAL ORTHOPHOSPHATE	6460	SP-9	0.37	1	0		0.37	0.37		0.37	0.37			MG/L
TOTAL ORTHOPHOSPHATE	6460	SP10+11	0.01	5	0	0.01	0.01	0.01	0.01	0.01	0.02			MG/L
TOTAL PHOSPHORUS	6297	SP2+3	0.13	5	1	0.08	0.12	0.14	0.08	0.09	0.26	0.05	0.05	MG/L
TOTAL PHOSPHORUS	6297	SP-4	0.14	5	0	0.08	0.14	0.14	0.08	0.07	0.25			MG/L
TOTAL PHOSPHORUS	6297	SP5+6	0.17	5	1	0.08	0.17	0.20	0.04	0.15	0.24	0.05	0.05	MG/L
TOTAL PHOSPHORUS	6297	SP-7	27.32	5	0	14.42	26.20	26.20	14.42	10.50	41.80			MG/L
TOTAL PHOSPHORUS	6297	SP8+9	10.17	5	0	0.54	10.16	10.16	0.54	9.67	10.90			MG/L
TOTAL PHOSPHORUS	6297	SP8+9,SP5+6	0.27	5	0	0.08	0.27	0.27	0.08	0.15	0.34			MG/L
TOTAL PHOSPHORUS	6297	SP-10	39.43	5	0	8.46	12.08	12.08	8.46	0.20	22.90			MG/L
TOTAL PHOSPHORUS	6297	SP-11	9.49	5	0	1.35	9.48	9.48	1.35	8.32	11.10			MG/L
TOTAL PHOSPHORUS	6297	SP11,SP5+6	0.26	5	1	0.09	0.26	0.30	0.06	0.23	0.34	0.13	0.13	MG/L
TOTAL PHOSPHORUS	6297	SP-12	62.13	5	0	36.82	38.93	38.93	36.82	2.34	80.40			MG/L
TOTAL PHOSPHORUS	6297	SP13+14	0.64	5	0	0.16	0.63	0.63	0.16	0.39	0.78			MG/L
TOTAL PHOSPHORUS	6297	SP13+14,SP2+3	0.13	5	1	0.08	0.13	0.15	0.08	0.09	0.27	0.06	0.06	MG/L
TOTAL PHOSPHORUS	6460	SP-7	0.04	5	0	0.02	0.04	0.04	0.02	0.03	0.06			MG/L
TOTAL PHOSPHORUS	6460	SP7,SP8	27.32	5	0	22.23	9.99	9.99	22.23	0.03	49.75			MG/L
TOTAL PHOSPHORUS	6460	SP7,SP9	0.10	5	0	0.12	0.10	0.10	0.12	0.03	0.30			MG/L
TOTAL PHOSPHORUS	6460	SP-8	61.10	1	0		61.10	61.10		61.10	61.10			MG/L
TOTAL PHOSPHORUS	6460	SP-9	0.36	1	0		0.36	0.36		0.36	0.36			MG/L
TOTAL PHOSPHORUS	6460	SP10+11	0.05	5	0	0.01	0.05	0.05	0.01	0.04	0.06			MG/L
TOTAL PHOSPHORUS	DMR1	SP-1	0.09	12	0	0.14	0.10	0.10	0.14	0.01	0.54			MG/L
TOTAL PHOSPHORUS	DMR2	SP-1	0.21	9	0	0.08	0.17	0.17	0.08	0.01	0.30			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP2+3	4.10	5	4	0.22	4.10	4.50		4.50	4.50	4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6297	SP-4	4.00	5	5	0.00	4.00					4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6297	SP5+6	4.00	5	5	0.00	4.00					4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6297	SP-7	976.16	5	0	521.77	933.20	933.20	521.77	363.00	1710.00			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP8+9	58.10	5	0	12.34	57.80	57.80	12.34	44.00	70.00			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP8+9,SP5+6	4.53	5	0	0.12	4.53	4.53	0.12	4.40	4.65			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP-10	597.10	5	1	376.76	592.20	739.25	212.37	540.00	1040.00	4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6297	SP-11	69.73	5	0	8.41	69.60	69.60	8.41	56.00	78.00			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP11,SP5+6	4.65	5	5	0.08	4.65					4.51	4.73	MG/L
TOTAL SUSPENDED SOLIDS	6297	SP-12	2829.90	5	0	1289.63	2593.40	2593.40	1289.63	707.00	4050.00			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP13+14	11.17	5	0	2.39	11.12	11.12	2.39	8.40	14.80			MG/L
TOTAL SUSPENDED SOLIDS	6297	SP13+14,SP2+3	4.17	5	4	0.24	4.17	4.60		4.60	4.60	4.04	4.08	MG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Flow-thru (continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
TOTAL SUSPENDED SOLIDS	6460	SP-7	4.00	5	5	0.00	4.00					4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6460	SP7,SP8	1924.70	5	4	4294.82	1924.70	9607.52		9607.52	9607.52	4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6460	SP7,SP9	9.54	5	4	12.38	9.54	31.68		31.68	31.68	4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	6460	SP-8	11800.00	1	0		11800.00	11800.00		11800.00	11800.00			MG/L
TOTAL SUSPENDED SOLIDS	6460	SP-9	38.00	1	0		38.00	38.00		38.00	38.00			MG/L
TOTAL SUSPENDED SOLIDS	6460	SP10+11	4.00	5	5	0.00	4.00					4.00	4.00	MG/L
TOTAL SUSPENDED SOLIDS	DMR1	SP-1	1.78	19	0	1.08	1.79	1.79	1.08	1.00	5.00			MG/L
TOTAL SUSPENDED SOLIDS	DMR2	SP-1	3.12	16	0	3.31	3.19	3.19	3.31	1.00	12.00			MG/L
TOTAL SUSPENDED SOLIDS	DMR3	SP-1	3.70	37	0	1.25	3.69	3.69	1.25	1.70	7.00			MG/L
TOTAL SUSPENDED SOLIDS	DMR4	SP-1	2.68	34	0	2.07	2.70	2.70	2.07	0.60	9.60			MG/L
ZINC	6297	SP2+3	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
ZINC	6297	SP-4	5.00	5	5	0.00	5.00					5.00	5.00	UG/L
ZINC	6297	SP5+6	5.18	5	4	0.40	5.18	5.90		5.90	5.90	5.00	5.00	UG/L
ZINC	6297	SP-7	1193.10	5	0	517.47	1127.60	1127.60	517.47	386.00	1640.00			UG/L
ZINC	6297	SP8+9	70.67	5	0	5.02	70.63	70.63	5.02	63.00	75.80			UG/L
ZINC	6297	SP8+9,SP5+6	5.83	5	0	0.43	5.83	5.83	0.43	5.57	6.59			UG/L
ZINC	6297	SP-10	890.91	5	0	226.60	885.00	885.00	226.60	625.00	1170.00			UG/L
ZINC	6297	SP-11	96.23	5	0	20.47	95.48	95.48	20.47	61.80	116.00			UG/L
ZINC	6297	SP11,SP5+6	6.07	5	4	0.23	6.07	6.45		6.45	6.45	5.89	6.10	UG/L
ZINC	6297	SP-12	2691.93	5	0	926.00	2612.00	2612.00	926.00	1180.00	3350.00			UG/L
ZINC	6297	SP13+14	12.89	5	0	1.63	12.87	12.87	1.63	10.90	15.40			UG/L
ZINC	6297	SP13+14,SP2+3	5.08	5	5	0.02	5.08					5.06	5.10	UG/L
ZINC	6460	SP-7	1.58	5	1	0.47	1.56	1.70	0.41	1.10	2.00	1.00	1.00	UG/L
ZINC	6460	SP7,SP8	2208.88	5	0	1371.95	615.25	615.25	1371.95	1.10	3069.47			UG/L
ZINC	6460	SP7,SP9	6.09	5	0	10.32	6.31	6.31	10.32	1.10	24.77			UG/L
ZINC	6460	SP-8	3770.00	1	0		3770.00	3770.00		3770.00	3770.00			UG/L
ZINC	6460	SP-9	30.20	1	0		30.20	30.20		30.20	30.20			UG/L
ZINC	6460	SP10+11	3.12	5	1	2.56	2.81	3.26	2.72	1.15	6.85	1.00	1.00	UG/L

Subcategory=Recirculating

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
AEROMONAS	6439	SP-2	84654.98	5	0	67476.60	82780.00	82780.00	67476.60	35000.00	200000.00			/100M
AEROMONAS	6439	SP-8	65215.77	5	0	75493.56	65540.00	65540.00	75493.56	27600.00	200000.00			/100M

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Recirculating
(continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
ALUMINUM	6439	SP-2	24.40	5	4	16.55	24.40	54.00		54.00	54.00	17.00	17.00	UG/L
ALUMINUM	6439	SP-3	431.48	5	0	146.25	424.60	424.60	146.25	247.00	583.00			UG/L
ALUMINUM	6439	SP-4	223.42	5	1	320.51	208.40	256.25	348.86	67.70	779.00	17.00	17.00	UG/L
ALUMINUM	6439	SP-8	61.94	5	1	33.69	61.12	72.15	26.50	47.10	109.00	17.00	17.00	UG/L
ALUMINUM	6439	SP9+11	37.03	5	2	19.85	36.73	49.88	11.80	38.10	61.70	17.00	17.00	UG/L
AMMONIA AS NITROGEN	6439	SP-2	1.38	5	0	0.41	1.37	1.37	0.41	1.09	2.08			MG/L
AMMONIA AS NITROGEN	6439	SP-3	2.24	5	0	0.71	2.22	2.22	0.71	1.60	3.05			MG/L
AMMONIA AS NITROGEN	6439	SP-4	2.60	5	0	0.97	2.52	2.52	0.97	1.10	3.69			MG/L
AMMONIA AS NITROGEN	6439	SP-8	2.12	5	0	0.95	2.06	2.06	0.95	1.02	3.28			MG/L
AMMONIA AS NITROGEN	6439	SP9+11	1.85	5	0	0.91	1.81	1.81	0.91	0.97	3.23			MG/L
BARIUM	6439	SP-2	27.56	5	0	0.84	27.56	27.56	0.84	26.40	28.60			UG/L
BARIUM	6439	SP-3	77.29	5	0	12.48	77.08	77.08	12.48	60.90	94.00			UG/L
BARIUM	6439	SP-4	54.61	5	0	30.60	54.34	54.34	30.60	38.20	109.00			UG/L
BARIUM	6439	SP-8	35.71	5	0	1.38	35.70	35.70	1.38	34.20	37.90			UG/L
BARIUM	6439	SP9+11	34.02	5	0	0.88	34.02	34.02	0.88	33.05	34.95			UG/L
BIOCHEMICAL OXYGEN DEMAND	6439	SP-2	48.93	5	0	7.56	48.80	48.80	7.56	38.00	59.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6439	SP-3	366.18	5	0	209.63	355.60	355.60	209.63	198.00	624.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6439	SP-4	187.12	5	0	238.17	190.40	190.40	238.17	68.00	616.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6439	SP-8	54.94	5	0	12.95	54.60	54.60	12.95	38.00	73.00			MG/L
BIOCHEMICAL OXYGEN DEMAND	6439	SP9+11	45.83	5	0	3.77	45.80	45.80	3.77	42.00	52.00			MG/L
BORON	6439	SP-2	270.46	5	0	26.66	270.20	270.20	26.66	236.00	309.00			UG/L
BORON	6439	SP-3	246.02	5	0	29.85	245.60	245.60	29.85	203.00	278.00			UG/L
BORON	6439	SP-4	237.10	5	0	26.97	236.80	236.80	26.97	208.00	270.00			UG/L
BORON	6439	SP-8	283.81	5	0	93.03	282.20	282.20	93.03	208.00	442.00			UG/L
BORON	6439	SP9+11	240.14	5	0	18.61	240.00	240.00	18.61	216.50	265.50			UG/L
CHEMICAL OXYGEN DEMAND (COD)	6439	SP-2	94.35	5	0	25.05	93.40	93.40	25.05	59.00	118.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6439	SP-3	776.30	5	0	222.20	770.60	770.60	222.20	532.00	1100.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6439	SP-4	249.92	5	0	225.92	249.60	249.60	225.92	134.00	652.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6439	SP-8	126.66	5	0	66.31	123.40	123.40	66.31	58.00	227.00			MG/L
CHEMICAL OXYGEN DEMAND (COD)	6439	SP9+11	119.35	5	0	42.62	118.50	118.50	42.62	86.50	189.50			MG/L
COPPER	6439	SP-2	15.91	5	0	1.35	15.90	15.90	1.35	14.00	17.60			UG/L
COPPER	6439	SP-3	70.54	5	0	11.79	70.26	70.26	11.79	51.30	83.50			UG/L
COPPER	6439	SP-4	48.85	5	0	63.19	49.98	49.98	63.19	20.40	163.00			UG/L
COPPER	6439	SP-8	19.07	5	0	1.45	19.06	19.06	1.45	16.90	20.70			UG/L
COPPER	6439	SP9+11	16.79	5	0	0.72	16.79	16.79	0.72	15.80	17.80			UG/L
FECAL STREPTOCOCCUS	6439	SP-2	65130.94	5	0	81484.80	55620.00	55620.00	81484.80	5100.00	200000.00			/100M
FECAL STREPTOCOCCUS	6439	SP-8	154354.32	5	0	86018.60	137200.00	137200.00	86018.60	40000.00	200000.00			/100M
HEXANE EXTRACTABLE MATERIAL	6439	SP-2	6.31	5	3	1.86	6.30	8.25	1.06	7.50	9.00	5.00	5.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6439	SP-3	10.60	5	0	4.23	10.50	10.50	4.23	7.00	17.50			MG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Recirculating
(continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
HEXANE EXTRACTABLE MATERIAL	6439	SP-4	6.62	5	1	1.39	6.60	7.00	1.22	5.50	8.50	5.00	5.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6439	SP-8	10.09	5	2	4.76	9.80	12.33	4.62	7.00	15.00	6.00	6.00	MG/L
HEXANE EXTRACTABLE MATERIAL	6439	SP9+11	6.49	5	3	1.52	6.45	7.75	1.77	6.50	9.00	5.00	6.00	MG/L
HEXANOIC ACID	6439	SP-2	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6439	SP-3	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6439	SP-4	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6439	SP-8	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
HEXANOIC ACID	6439	SP9+11	10.00	2	2	0.00	10.00					10.00	10.00	UG/L
IRON	6439	SP-2	95.22	5	1	54.43	94.08	114.60	33.81	79.50	146.00	12.00	12.00	UG/L
IRON	6439	SP-3	1502.38	5	0	415.57	1487.00	1487.00	415.57	935.00	1970.00			UG/L
IRON	6439	SP-4	716.01	5	0	1248.11	757.60	757.60	1248.11	177.00	2990.00			UG/L
IRON	6439	SP-8	117.01	5	1	60.38	116.80	143.00	16.87	123.00	161.00	12.00	12.00	UG/L
IRON	6439	SP9+11	75.92	5	2	58.41	75.90	118.50	4.27	114.00	122.50	12.00	12.00	UG/L
MANGANESE	6439	SP-2	114.92	5	0	39.40	112.04	112.04	39.40	53.20	160.00			UG/L
MANGANESE	6439	SP-3	575.65	5	0	122.40	572.20	572.20	122.40	398.00	720.00			UG/L
MANGANESE	6439	SP-4	246.12	5	0	264.25	245.60	245.60	264.25	100.00	715.00			UG/L
MANGANESE	6439	SP-8	128.53	5	0	21.48	128.20	128.20	21.48	108.00	158.00			UG/L
MANGANESE	6439	SP9+11	119.28	5	0	20.62	118.98	118.98	20.62	104.00	147.50			UG/L
NITRATE/NITRITE	6439	SP-2	118.55	5	0	14.40	118.36	118.36	14.40	98.80	133.00			MG/L
NITRATE/NITRITE	6439	SP-3	86.20	5	0	16.73	85.74	85.74	16.73	60.70	100.00			MG/L
NITRATE/NITRITE	6439	SP-4	82.00	5	0	13.78	81.74	81.74	13.78	66.10	95.90			MG/L
NITRATE/NITRITE	6439	SP-8	77.91	5	0	21.48	77.30	77.30	21.48	54.10	101.00			MG/L
NITRATE/NITRITE	6439	SP9+11	105.90	5	0	10.35	105.78	105.78	10.35	89.50	115.00			MG/L
SELENIUM	6439	SP-2	9.30	5	4	9.77	9.30	2.50		2.50	2.50	2.00	20.00	UG/L
SELENIUM	6439	SP-3	16.68	5	4	7.42	16.68	3.40		3.40	3.40	20.00	20.00	UG/L
SELENIUM	6439	SP-4	7.21	5	3	7.56	7.08	5.70	2.55	3.90	7.50	2.00	20.00	UG/L
SELENIUM	6439	SP-8	2.00	5	5	0.00	2.00					2.00	2.00	UG/L
SELENIUM	6439	SP9+11	6.37	5	2	4.71	6.04	5.73	4.88	2.55	11.35	2.00	11.00	UG/L
SETTLEABLE SOLIDS	6439	SP-2	0.14	5	4	0.09	0.14	0.30		0.30	0.30	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6439	SP-3	25.62	5	0	2.70	25.60	25.60	2.70	23.00	30.00			mL/L
SETTLEABLE SOLIDS	6439	SP-4	11.39	5	0	16.48	9.75	9.75	16.48	0.75	39.00			mL/L
SETTLEABLE SOLIDS	6439	SP-8	0.65	5	1	0.34	0.64	0.78	0.19	0.50	0.90	0.10	0.10	mL/L
SETTLEABLE SOLIDS	6439	SP9+11	0.17	5	2	0.11	0.16	0.20	0.13	0.10	0.35	0.10	0.10	mL/L
TOTAL COLIFORM	6439	SP-2	209212.56	5	0	103619.07	87020.00	87020.00	103619.07	2900.00	200000.00			/100M
TOTAL COLIFORM	6439	SP-8	159608.05	5	0	68772.81	151200.00	151200.00	68772.81	55000.00	200000.00			/100M
TOTAL KJELDAHL NITROGEN	6439	SP-2	3.83	5	0	1.61	3.81	3.81	1.61	2.76	6.65			MG/L
TOTAL KJELDAHL NITROGEN	6439	SP-3	55.62	5	0	22.90	53.88	53.88	22.90	24.30	82.40			MG/L
TOTAL KJELDAHL NITROGEN	6439	SP-4	17.71	5	0	12.39	15.91	15.91	12.39	3.86	33.00			MG/L
TOTAL KJELDAHL NITROGEN	6439	SP-8	21.48	5	0	33.80	22.36	22.36	33.80	6.22	82.80			MG/L

Appendix D: Summary Statistics at Each Sample Point for Pollutants of Concern

Subcategory=Recirculating
(continued)

Analyte	Episode	Sample Point	Est LTA	Total Number Values	Number of ND	Obs Std Dev	Obs Mean Value	Mean Value NC	Std Dev NC	Min Value NC	Max Value NC	Min Value ND	Max Value ND	Unit
TOTAL KJELDAHL NITROGEN	6439	SP9+11	4.37	5	0	1.37	4.32	4.32	1.37	2.60	5.80			MG/L
TOTAL ORTHOPHOSPHATE	6439	SP-2	9.96	5	0	1.65	9.94	9.94	1.65	8.72	12.60			MG/L
TOTAL ORTHOPHOSPHATE	6439	SP-3	6.81	5	0	0.26	6.81	6.81	0.26	6.56	7.24			MG/L
TOTAL ORTHOPHOSPHATE	6439	SP-4	6.84	5	0	0.61	6.83	6.83	0.61	5.99	7.58			MG/L
TOTAL ORTHOPHOSPHATE	6439	SP-8	8.36	5	0	0.73	8.36	8.36	0.73	7.58	9.52			MG/L
TOTAL ORTHOPHOSPHATE	6439	SP9+11	9.45	5	0	2.85	9.42	9.42	2.85	7.98	14.50			MG/L
TOTAL PHOSPHORUS	6439	SP-2	11.32	5	0	1.94	11.29	11.29	1.94	8.83	14.10			MG/L
TOTAL PHOSPHORUS	6439	SP-3	12.20	5	0	5.77	11.96	11.96	5.77	7.32	18.40			MG/L
TOTAL PHOSPHORUS	6439	SP-4	11.13	5	0	4.33	11.06	11.06	4.33	7.95	18.60			MG/L
TOTAL PHOSPHORUS	6439	SP-8	10.03	5	0	1.70	10.01	10.01	1.70	8.71	12.70			MG/L
TOTAL PHOSPHORUS	6439	SP9+11	10.92	5	0	3.85	10.86	10.86	3.85	8.27	17.50			MG/L
TOTAL SUSPENDED SOLIDS	6439	SP-2	46.29	5	0	6.30	46.20	46.20	6.30	38.00	55.00			MG/L
TOTAL SUSPENDED SOLIDS	6439	SP-3	581.74	5	0	334.20	548.60	548.60	334.20	180.00	1030.00			MG/L
TOTAL SUSPENDED SOLIDS	6439	SP-4	272.63	5	0	407.46	281.60	281.60	407.46	84.00	1010.00			MG/L
TOTAL SUSPENDED SOLIDS	6439	SP-8	58.27	5	0	16.89	57.20	57.20	16.89	30.00	74.00			MG/L
TOTAL SUSPENDED SOLIDS	6439	SP9+11	47.09	5	0	12.07	46.60	46.60	12.07	28.50	61.00			MG/L
ZINC	6439	SP-2	31.94	5	1	17.88	31.88	39.60	5.37	34.80	47.30	1.00	1.00	UG/L
ZINC	6439	SP-3	557.48	5	0	156.64	552.80	552.80	156.64	365.00	781.00			UG/L
ZINC	6439	SP-4	239.41	5	0	366.75	248.26	248.26	366.75	69.90	904.00			UG/L
ZINC	6439	SP-8	68.12	5	0	8.92	68.00	68.00	8.92	57.50	79.70			UG/L
ZINC	6439	SP9+11	38.26	5	2	34.69	38.03	62.72	11.02	50.05	70.05	1.00	1.00	UG/L

APPENDIX E
MODIFIED DELTA-LOG NORMAL DISTRIBUTION

APPENDIX E:
MODIFIED DELTA-LOGNORMAL DISTRIBUTION

This appendix describes the modified delta-lognormal distribution and the estimation of the episode long-term averages and variability factors used to calculate the limitations and standards.[1] This appendix provides the statistical methodology that was used to obtain the results presented in Chapter 8.

E.1 BASIC OVERVIEW OF THE MODIFIED DELTA-LOGNORMAL DISTRIBUTION

EPA selected the modified delta-lognormal distribution to model pollutant effluent concentrations from the aquatic animals industry in developing the long-term averages and variability factors. A typical effluent data set from a sampling episode or self-monitoring episode (see Chapter 8 for a discussion of the data associated with these episodes) consists of a mixture of measured (detected) and non-detected values. The modified delta-lognormal distribution is appropriate for such data sets because it models the data as a mixture of measurements that follow a lognormal distribution and non-detect measurements that occur with a certain probability. The model also allows for the possibility that non-detect measurements occur at multiple sample-specific detection limits. Because the data appeared to fit the modified delta-lognormal model reasonably well, EPA has determined that this model is appropriate for these data.

The modified delta-lognormal distribution is a modification of the 'delta distribution' originally developed by Aitchison and Brown.[2] While this distribution was originally developed to model economic data, other researchers have shown the application to environmental data.[3] The resulting mixed distributional model, which combines a continuous density portion with a discrete-valued spike at zero, is also known as the delta-lognormal distribution. The delta in the name refers to the proportion of the overall distribution contained in the discrete distributional spike at zero; that is, the proportion of zero amounts. The remaining non-zero, non-censored (NC) amounts are grouped together and fit to a lognormal distribution.

EPA modified this delta-lognormal distribution to incorporate multiple detection limits. In the modification of the delta portion, the single spike located at zero is replaced by a discrete distribution made up of multiple spikes. Each spike in this modification is associated with a distinct sample-specific detection limit associated with non-detected

---

[1] In the remainder of this appendix, references to 'limitations' includes 'standards.'

[2] Aitchison, J. and Brown, J.A.C. (1963) The Lognormal Distribution. Cambridge University Press, pages 87-99.

[3] Owen, W.J. and T.A. DeRouen. 1980. "Estimation of the Mean for Lognormal Data Containing Zeroes and Left-Censored Values, with Applications to the Measurement of Worker Exposure to Air Contaminants." *Biometrics*, 36:707-719.

(ND) measurements in the database.[4] A lognormal density is used to represent the set of measured values. This modification of the delta-lognormal distribution is illustrated in Figure 1.

The following two subsections describe the delta and lognormal portions of the modified delta-lognormal distribution in further detail.

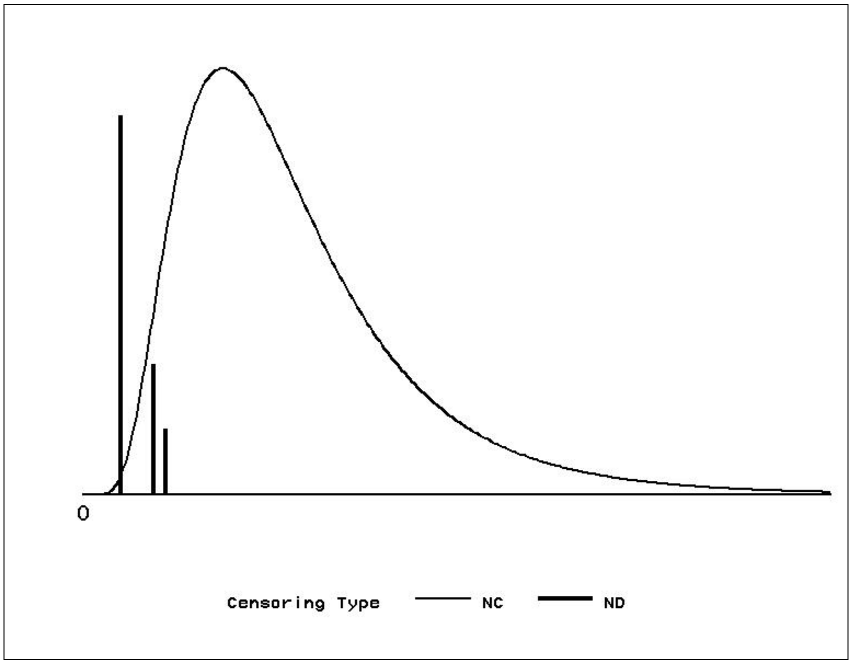


Figure E-1. Modified Delta-Lognormal Distribution

E.2 CONTINUOUS AND DISCRETE PORTIONS OF THE MODIFIED DELTA-LOGNORMAL DISTRIBUTION

The discrete portion of the modified delta-lognormal distribution models the non-detected values corresponding to the k reported sample-specific detection limits. In the model, δ represents the proportion of non-detected values in the dataset and is the sum of smaller fractions, δ_i, each representing the proportion of non-detected values associated with each distinct detection limit value. By letting D_i equal the value of the i^{th} smallest distinct detection limit in the data set and the random variable X_D represents a randomly chosen

[4] Previously, EPA had modified the delta-lognormal model to account for non-detected measurements by placing the distributional "spike" at a single positive value, usually equal to the nominal method detection limit, rather than at zero. For further details, see Kahn and Rubin, 1989. This adaptation was used in developing limitations and standards for the organic chemicals, plastics, and synthetic fibers (OCPSF) and pesticides manufacturing rulemakings. EPA has used the current modification in several, more recent, rulemakings.

non-detected measurement, the cumulative distribution function of the discrete portion of the modified delta-lognormal model can be mathematically expressed as:

$$\Pr\left(X_D \leq c\right) = \frac{1}{\delta} \sum_{i:D_i \leq c} \delta_i \qquad 0 < c \tag{E-1}$$

The mean and variance of this discrete distribution can be calculated using the following formulas:

$$E(X_D) = \frac{1}{\delta} \sum_{i=1}^{k} \delta_i \, D_i \tag{E-2}$$

$$Var(X_D) = \frac{1}{\delta} \sum_{i=1}^{k} \delta_i \left(D_i - E(X_D)\right)^2 \tag{E-3}$$

The continuous, lognormal portion of the modified delta-lognormal distribution was used to model the detected measurements from the aquatic animals industry database. The cumulative probability distribution of the continuous portion of the modified delta-lognormal distribution can be mathematically expressed as:

$$\Pr\left[X_C \leq c\right] = \Phi\left[\frac{\ln(c) - \mu}{\sigma}\right] \tag{E-4}$$

where the random variable X_C represents a randomly chosen detected measurement, Φ is the standard normal distribution, and μ and σ are parameters of the distribution.

The expected value, E(X_C), and the variance, Var(X_C), of the lognormal distribution can be calculated as:

$$E\left(X_C\right) = \exp\left(\mu + \frac{\sigma^2}{2}\right) \tag{E-5}$$

$$Var\left(X_C\right) = \left[E\left(X_C\right)\right]^2 \left(\exp\left(\sigma^2\right) - 1\right) \tag{E-6}$$

E.3 COMBINING THE CONTINUOUS AND DISCRETE PORTIONS

The continuous portion of the modified delta-lognormal distribution is combined with the discrete portion to model data sets that contain a mixture of non-detected and detected measurements. It is possible to fit a wide variety of observed effluent data sets to the modified delta-lognormal distribution. Multiple detection limits for non-detect measurements are incorporated, as are measured ("detected") values. The same basic framework can be used even if there are no non-detected values in the data set (in this case, it is the same as the lognormal distribution). Thus, the modified delta-lognormal distribution offers a large degree of flexibility in modeling effluent data.

The modified delta-lognormal random variable U can be expressed as a combination of three other independent variables, that is,

$$U = I_u X_D + (1 - I_u) X_C \qquad \text{(E-7)}$$

where X_D represents a random non-detect from the discrete portion of the distribution, X_C represents a random detected measurement from the continuous lognormal portion, and I_u is an indicator variable signaling whether any particular random measurement, u, is non-detected or non-censored (that is, I_u=1 if u is non-detected; I_u=0 if u is non-censored). Using a weighted sum, the cumulative distribution function from the discrete portion of the distribution (equation 1) can be combined with the function from the continuous portion (equation 4) to obtain the overall cumulative probability distribution of the modified delta-lognormal distribution as follows,

$$\Pr(U \le c) = \sum_{i:D_i \le c} \delta_i + (1-\delta)\Phi\left[\frac{\ln(c) - \mu}{\sigma}\right] \qquad \text{(E-8)}$$

where D_i is the value of the i^{th} sample-specific detection limit.The expected value of the random variable *U* can be derived as a weighted sum of the expected values of the discrete and continuous portions of the distribution (equations 2 and 5, respectively) as follows

$$E(U) = \delta E(X_D) + (1-\delta) E(X_C) \qquad \text{(E-9)}$$

In a similar manner, the expected value of the random variable squared can be written as a weighted sum of the expected values of the squares of the discrete and continuous portions of the distribution as follows

$$E(U^2) = \delta E(X_D^2) + (1-\delta) E(X_C^2) \qquad \text{(E-10)}$$

Although written in terms of U, the following relationship holds for all random variables, U, X_D, and X_C.

$$E\left(U^2\right) = Var(U) + \left[E(U)\right]^2 \quad \text{(E-11)}$$

So using equation 11 to solve for Var(U), and applying the relationships in equations 9 and 10, the variance of *U* can be obtained as

$$\mathrm{Var}(U) = \delta\left(\mathrm{Var}(X_D) + \left[\mathrm{E}(X_D)\right]^2\right) + (1-\delta)\left(\mathrm{Var}(X_C) + \left[\mathrm{E}(X_C)\right]^2\right) - \left[\mathrm{E}(U)\right]^2 \quad \text{(E-12)}$$

E.4 EPISODE ESTIMATES UNDER THE MODIFIED DELTA-LOGNORMAL DISTRIBUTION

In order to use the modified delta-lognormal model to calculate the limitations, the parameters of the distribution are estimated from the data. These estimates are then used to calculate the limitations.The parameters $\hat{\delta}_\iota$ and $\hat{\delta}$ are estimated from the data using the following formulas:

$$\hat{\delta}_i = \frac{1}{n}\sum_{j=1}^{n_d} I\left(d_j = D_i\right)$$
$$\hat{\delta} = \frac{n_d}{n} \quad \text{(E-13)}$$

where n_d is the number of non-detected measurements, d_j, j = 1 to n_d, are the detection limits for the non-detected measurements, *n* is the number of measurements (both detected and non-detected) and I(…) is an indicator function equal to one if the phrase within the parentheses is true and zero otherwise. The "hat" over the parameters indicates that they are estimated from the data.

The expected value and the variance of the delta portion of the modified delta-lognormal distribution can be calculated from the data as:

$$\hat{E}\left(X_D\right) = \frac{1}{\hat{\delta}}\sum_{i=1}^{k}\hat{\delta}_i D_i \quad \text{(E-14)}$$

$$\hat{V}ar\left(X_D\right) = \frac{1}{\hat{\delta}}\sum_{i=1}^{k}\hat{\delta}_i\left(D_i - \hat{E}\left(X_D\right)\right)^2 \quad \text{(E-15)}$$

The parameters of the continuous portion of the modified delta-lognormal distribution, $\hat{\mu}$ and $\hat{\sigma}^2$, are estimated by

$$\hat{\mu} = \sum_{i=1}^{n_c} \frac{\ln(x_i)}{n_c}$$
$$\hat{\sigma}^2 = \sum_{i=1}^{n_c} \frac{\left(\ln(x_i) - \hat{\mu}\right)^2}{n_c - 1} \qquad \text{(E-16)}$$

where x_i is the i[th] detected measurement value and n_c is the number of detected measurements. Note that $n = n_d + n_c$.

The expected value and the variance of the lognormal portion of the modified delta-lognormal distribution can be calculated from the data as:

$$\hat{E}(X_C) = \exp\left(\hat{\mu} + \frac{\hat{\sigma}^2}{2}\right) \qquad \text{(E-17)}$$

$$\hat{V}ar(X_C) = \left[\hat{E}(X_C)\right]^2 \left(\exp\left(\hat{\sigma}^2\right) - 1\right) \qquad \text{(E-18)}$$

Finally, the expected value and variance of the modified delta-lognormal distribution can be estimated using the following formulas:

$$\hat{E}(U) = \hat{\delta}\,\hat{E}(X_D) + \left(1 - \hat{\delta}\right)\hat{E}(X_C) \qquad \text{(E-19)}$$

$$\hat{V}ar(U) = \hat{\delta}\left(\hat{V}ar(X_D) + \left[\hat{E}(X_D)\right]^2\right) + \left(1 - \hat{\delta}\right)\left(\hat{V}ar(X_C) + \left[\hat{E}(X_C)\right]^2\right) - \left[\hat{E}(U)\right]^2 \qquad \text{(E-20)}$$

Equations 17 through 20 are particularly important in the estimation of episode long-term averages and variability factors as described in the following sections. These sections are preceded by a section that identifies the episode data set requirements.

Example:

Consider a facility that has 10 samples with the following concentrations:

Sample number	Measurement Type	Concentration (mg/L)
1	ND	10
2	ND	15
3	ND	15
4	ND	20
5	NC	25
6	NC	25
7	NC	30
8	NC	35
9	NC	35
10	NC	40

The ND components of the variance equation are:

$D_1 = 10, \hat{\delta}_1 = 1/10 D_2 = 15, \hat{\delta}_2 = 1/5 D_3 = 20, \hat{\delta}_3 = 1/10.$

Since $\hat{\delta} = 2/5$, the expected value and the variance of the discrete portion of the modified delta-lognormal distribution are

$$\hat{E}\left(X_D\right) = \frac{1}{2/5}\left(\frac{1}{10}\times 10 + \frac{1}{5}\times 15 + \frac{1}{10}\times 20\right) = 15,$$

$$\hat{V}ar\left(X_D\right) = \frac{1}{2/5}\left(\frac{1}{10}\times(10-15)^2 + \frac{1}{5}\times(15-15)^2 + \frac{1}{10}\times(20-15)^2\right) = 12.5.$$

The mean and variance of the log NC values are calculated as

follows: $\hat{\mu} = \frac{\sum_{i=1}^{n_c} \ln\left(x_i\right)}{n_c} = \frac{\left(2\times\ln(25) + \ln(30) + 2\times\ln(35) + \ln(40)\right)}{6} = 3.44$

$$\hat{\sigma}^2 = \frac{\sum_{i=1}^{n_c}\left(\ln\left(x_i\right)-\hat{\mu}\right)^2}{n_c-1} = \frac{\left(2\times\left(\ln(25)-3.44\right)^2\right)+\left(\ln(30)-3.44\right)^2+\left(2\times\left(\ln(35)-3.44\right)^2\right)+\left(\ln(40)-3.44\right)^2}{5} = 0.0376$$

Then, the expected value and the variance of the lognormal portion of the modified delta-lognormal distribution are

$$\hat{E}\left(X_C\right) = \exp\left(3.44+\frac{0.0376}{2}\right) = 31.779$$

$$\hat{V}ar\left(X_C\right) = [31.779]^2\left(\exp(0.0376)-1\right) = 38.695.$$

The expected value and variance of the modified delta-lognormal distribution are

$$\hat{E}(U) = \frac{2}{5}\times 15+\left(1-\frac{2}{5}\right)\times 31.779 = 25.063$$

$$\hat{V}ar(U) = \frac{2}{5}\times\left(12.5+15^2\right)+\left(1-\frac{2}{5}\right)\times\left(38.695+31.779^2\right)-25.067^2 = 95.781.$$

E.4.1 Episode Data Set Requirements

Estimates of the necessary parameters for the lognormal portion of the distribution can be calculated with as few as two distinct detected values in a data set. (In order to calculate the variance of the modified delta-lognormal distribution, two distinct detected values are the minimum number that can be used and still obtain an estimate of the variance for the distribution.)

If an episode data set for a pollutant contained three or more observations with two or more distinct detected concentration values, then EPA used the modified delta-lognormal distribution to calculate long-term averages and variability factors. If the episode data set for a pollutant did not meet these requirements, EPA used an arithmetic average to calculate the episode long-term average and excluded the dataset from the variability factor calculations (because the variability could not be calculated).

In statistical terms, each measurement was assumed to be independently and identically distributed from the other measurements of that pollutant in the episode data set.

The next two sections apply the modified delta-lognormal distribution to the data for estimating episode long-term averages and variability factors for the aquatic animals industry.

E.4.2 Estimation of Episode Long-Term Averages

If an episode dataset for a pollutant mets the requirements described in the last section, then EPA calculated the long-term average using equation 19. Otherwise, EPA calculated the long-term average as the arithmetic average of the daily values where the sample-specific detection limit was used for each non-detected measurement.

E.4.3 Estimation of Episode Variability Factors

For each episode, EPA estimated the daily variability factors by fitting a modified delta-lognormal distribution to the daily measurements for each pollutant. In contrast, EPA estimated monthly variability factors by fitting a modified delta-lognormal distribution to the monthly averages for the pollutant at the episode. EPA developed these averages using the same number of measurements as the assumed monitoring frequency for the pollutant. EPA is assuming that all pollutants will be monitored weekly (approximately four times a month).[5]

E.4.3.1 Estimation of Episode Daily Variability Factors

The episode daily variability factor is a function of the expected value, and the 99th percentile of the modified delta-lognormal distribution fit to the daily concentration values of the pollutant in the wastewater from the episode. The expected value, was estimated using equation 19 (the expected value is the same as the episode long-term average).

The 99th percentile of the modified delta-lognormal distribution fit to each data set was estimated by using an iterative approach. First, the pollutant-specific detection limits were ordered from smallest to largest. Next, the cumulative distribution function, p, for each detection limit was computed. The general form, for a given value c, was:

$$p = \sum_{i:D_i \le c} \hat{\delta}_i + \left(1 - \hat{\delta}\right) \Phi\left[\frac{\ln\left(c\right) - \hat{\mu}}{\hat{\sigma}}\right] \qquad \text{(E-21)}$$

where Φ is the standard normal cumulative distribution function. Next, the interval containing the 99th percentile was identified. Finally, the 99th percentile of the modified delta-lognormal distribution was calculated. The following steps were completed to compute the estimated 99th percentile of each data subset:

[5] Compliance with the monthly average limitations will be required in the final rulemaking regardless of the number of samples analyzed and averaged.

Step 1 Using equation 21, k values of p at c=D_m, m=1,...,k were computed and labeled p_m.

Step 2 The smallest value of m (m=1,...,k), such that $p_m \geq 0.99$, was determined and labeled as p_j. If no such m existed, steps 3 and 4 were skipped and step 5 was computed instead.

Step 3 Computed $p^* = p_j - \hat{\delta}_j$.

Step 4 If $p^* < 0.99$, then $\hat{P}99 = D_j$ else if $p^* \geq 0.99$, then

$$\hat{P}99 = \exp\left(\hat{\mu} + \hat{\sigma}\Phi^{-1}\left[\frac{0.99 - \sum_{i=1}^{j-1}\hat{\delta}_i}{1-\hat{\delta}}\right]\right) \qquad \text{(E-22)}$$

where Φ^{-1} is the inverse normal distribution function.

Step 5 If no such m exists such that $p_m > 0.99$ (m=1,...,k), then

$$\hat{P}99 = \exp\left(\hat{\mu} + \hat{\sigma}\Phi^{-1}\left[\frac{0.99-\hat{\delta}}{1-\hat{\delta}}\right]\right) \qquad \text{(E-23)}$$

The episode daily variability factor, VF1, was then calculated as:

$$VF1 = \frac{\hat{P}99}{\hat{E}(U)} \qquad \text{(E-24)}$$

Example:

Since no such m exists such that $p_m > 0.99$ (m=1,...,k),

$$\hat{P}99 = \exp\left(3.44 + 0.194 \times \Phi^{-1}\left[\frac{0.99-0.4}{1-0.4}\right]\right) = 47.126.$$

The episode daily variability factor, VF1, was then calculated as:

$$VF1 = \frac{47.126}{25.067} = 1.880.$$

E.4.3.2 Estimation of Episode Monthly Variability Factors

EPA estimated the monthly variability factors by fitting a modified delta-lognormal distribution to the monthly averages. These equations use the same basic parameters, μ and σ, calculated for the daily variability factors. Episode monthly variability factors were based on 4-day monthly averages because the monitoring frequency was assumed to be weekly (approximately four times a month).

Before estimating the episode monthly variability factors, EPA considered whether autocorrelation was likely to be present in the effluent data. When data are said to be positively autocorrelated, it means that measurements taken at specific time intervals (such as 1 day or 1 week apart) are related. For example, positive autocorrelation would be present in the data if the final effluent concentration of TSS was relatively high one day and was likely to remain at similar high values the next and possibly succeeding days. Because EPA is assuming that the pollutants will be monitored weekly, EPA based the monthly variability factors on the distribution of the averages of four measurements. If concentrations measured on consecutive weeks were positively correlated, then the autocorrelation would have had an effect on the estimate of the variance of the monthly average and thus on the monthly variability factor. Adjustments for positive autocorrelation would increase the values of the variance and monthly variability factor. (The estimate of the long-term average and the daily variability factor are generally only slightly affected by autocorrelation.)

EPA has not incorporated an autocorrelation adjustment into its estimates of the monthly variability factors. In some industries, measurements in final effluent are likely to be similar from one day (or week) to the next because of the consistency from day-to-day in the production processes and in final effluent discharges due to the hydraulic retention time of wastewater in basins, holding tanks, and other components of wastewater treatment systems. To determine if autocorrelation exists in the data, a statistical evaluation is necessary and will be considered before the final rule. To estimate autocorrelation in the data, many measurements for each pollutant would be required with values for equally spaced intervals over an extended period of time. If such data are available for the final rule, EPA intends to perform a statistical evaluation of autocorrelation and if necessary, provide any adjustments to the limitations.

Thus, in calculating the monthly variability factors for the proposal, EPA assumed that consecutive daily measurements were not correlated. In order to calculate the 4-day variability factors (VF4), EPA further assumed that the approximating distribution of $\overline{U}_4$, the sample mean for a random sample of four independent concentrations, was derived from the modified delta-lognormal distribution.[6] To obtain the expected value of the 4-day averages, equation 19 is modified for the mean of the distribution of 4-day averages in equation 25:

$$\hat{E}\left(\overline{U}_4\right) = \hat{\delta}_4' \hat{E}\left(\overline{X}_4\right)_D + \left(1 - \hat{\delta}_4'\right)\hat{E}\left(\overline{X}_4\right)_C \tag{25}$$

where $\hat{\delta}_4'$ denotes the probability of detection of the 4-day average, $\left(\overline{X}_4\right)_D$ denotes the mean of the discrete portion of the distribution of the average of four independent concentrations, (i.e., when all observations are non-detected values), and $\left(\overline{X}_4\right)_C$ denotes the mean of the continuous lognormal portion (i.e., when any observations are detected).

First, it was assumed that the probability of detection (δ) on each of the four days was independent of the measurements on the other three days (as explained in Section E.4.1, daily measurements were also assumed to be independent) and therefore, $\delta'_4 = \delta^4$. Because the measurements are assumed to be independent, the following relationships hold:

$$\begin{aligned} &\hat{E}\left(\overline{U}_4\right) = \hat{E}\left(U\right) \\ &\hat{V}ar\left(\overline{U}_4\right) = \frac{\hat{V}ar\left(U\right)}{4} \\ &\hat{E}\left(\left(\overline{X}_4\right)_D\right) = \hat{E}\left(X_D\right) \\ &\hat{V}ar\left(\left(\overline{X}_4\right)_D\right) = \frac{\hat{V}ar\left(X_D\right)}{4} \end{aligned} \tag{E-26}$$

Substituting into equation 26 and solving for the expected value of the continuous portion of the distribution gives:

$$\hat{E}\left(\overline{X}_4\right)_C = \frac{\hat{E}\left(U\right) - \hat{\delta}^4 \hat{E}\left(X_D\right)}{1 - \hat{\delta}^4} \tag{E-27}$$

Using the relationship in equation 20 for the averages of 4 daily measurements and substituting terms from equation 25 and solving for the variance of the continuous portion of $\overline{U}_4$ gives:

[6] As described in Section 8.4, when non-detected measurements are aggregated with non-censored measurements, EPA determined that the result should be considered non-censored.

$$\hat{V}ar\left(\overline{X}_4\right)_C = \frac{\frac{\hat{V}ar(U)}{4}+\left[\hat{E}(U)\right]^2 - \hat{\delta}^4\left(\frac{\hat{V}ar(X_D)}{4}+\left[\hat{E}(X_D)\right]^2\right)}{1-\hat{\delta}^4} - \left[\hat{E}\left(\overline{X}_4\right)_C\right]^2 \quad \text{(E-28)}$$

Using equations 17 and 18 and solving for the parameters of the lognormal distribution describing the distribution of $\left(\overline{X}_4\right)_C$ gives:

$$\hat{\sigma}_4^2 = \ln\left(\frac{\hat{V}ar\left(\overline{X}_4\right)_C}{\left(\hat{E}\left(\overline{X}_4\right)_C\right)^2}+1\right)$$

and (E-29)

$$\hat{\mu}_4 = \ln\left(\hat{E}\left(\overline{X}_4\right)_C\right) - \frac{\hat{\sigma}_4^2}{2}$$

In finding the estimated 95[th] percentile of the average of four observations, four non-detects, not all at the same sample-specific detection limit, can generate an average that is not necessarily equal to D_1, D_2,..., or D_k. Consequently, more than k discrete points exist in the distribution of the 4-day averages. For example, the average of four non-detects at k=2 detection limits, are at the following discrete points with the associated probabilities:

i	D_i^*	δ_i^*
1	D_1	δ_1^4
2	$\left(3D_1 + D_2\right)/4$	$4\delta_1^3\delta_2$
3	$\left(2D_1 + 2D_2\right)/4$	$6\delta_1^2\delta_2^2$
4	$\left(D_1 + 3D_2\right)/4$	$4\delta_1\delta_2^3$
5	D_2	δ_2^4

When all four observations are non-detected values, and when k distinct non-detected values exist, the multinomial distribution can be used to determine associated probabilities. That is,

$$\Pr\left[\overline{U}_4 = \frac{\sum_{i=1}^{k} u_i D_i}{4}\right] = \frac{4!}{u_1!\,u_2!\ldots u_k!}\prod_{i=1}^{k}\delta_i^{u_i} \qquad \text{(E-30)}$$

where u_i is the number of non-detected measurements in the data set with the D_i detection limit. The maximum number of possible discrete points, k^*, for k=1,2,3,4, and 5 are as follows:

k	k^*
1	1
2	5
3	15
4	35
5	70

To find the estimated 95th percentile of the distribution of the average of four observations, the same basic steps (described in Section E.4.3.1) as for the 99th percentile of the distribution of daily observations, were used with the following changes:

Step 1 Change P_{99} to P_{95}, and 0.99 to 0.95.

Step 2 Change D_m to D_m^*, the weighted averages of the sample-specific detection limits.

Step 3 Change δ_i to δ_i^*.

Step 4 Change k to k^*, the number of possible discrete points based on k detection limits.

Step 5 Change the estimates of δ, $\hat{\mu}$,and $\hat{\sigma}$ to estimates of δ^4, $\hat{\mu}_4$ and $\hat{\sigma}_4^2$ respectively.

Then, using $\hat{E}\left(\overline{U}_4\right) = \hat{E}\left(U\right)$, the estimate of the episode 4-day variability factor, VF4, was calculated as:

$$VF4 = \frac{\hat{P}95}{\hat{E}\left(U\right)} \qquad \text{(E-31)}$$

Example:

$$\hat{E}\left(\overline{U}_4\right) = 25.067$$

$$\hat{V}ar\left(\overline{U}_4\right) = \frac{95.781}{4} = 23.95$$

$$\hat{E}\left(\left(\overline{X}_4\right)_D\right) = 15$$

$$\hat{V}ar\left(\left(\overline{X}_4\right)_D\right) = \frac{12.5}{4} = 3.125$$

$$\hat{E}\left(\overline{X}_4\right)_C = \frac{25.067 - 0.4^4 \times 15}{1 - 0.4^4} = \frac{24.683}{0.974} = 25.331.$$

$$\hat{V}ar\left(\overline{X}_4\right)_C = \frac{23.95 + 25.067^2 - 0.4^4 \times \left(3.125 + 15^2\right)}{1 - 0.4^4} - 25.331^2 = 21.789$$

$$\hat{\sigma}_4^2 = \ln\left(\frac{21.789}{25.331^2} + 1\right) = 0.0334 \quad \hat{\delta}_4' = \hat{\delta}^4 = \left(\frac{2}{5}\right)^4 = 0.0256$$

$$\hat{\mu}_4 = \ln(25.331) - \frac{0.0334}{2} = 3.215.$$

$$\hat{P}95 = \exp\left(3.215 + 0.183 \times \Phi^{-1}\left[\frac{0.95 - 0.4^4}{1 - 0.4^4}\right]\right) = 33.683.$$

$$VF4 = \frac{33.683}{25.067} = 1.344.$$

E.4.3.3 Evaluation of Episode Variability Factors

Estimates of the necessary parameters for the lognormal portion of the distribution can be calculated with as few as two distinct measured values in a data set (in order to calculate the variance); however, these estimates can be unstable (as can estimates from larger data sets). As stated in Section E.4.1, EPA used the modified delta-lognormal distribution to develop episode variability factors for data sets that had a three or more observations with two or more distinct measured concentration values.

To identify situations producing unexpected results, EPA reviewed all of the variability factors and compared daily to monthly variability factors. EPA used several criteria to determine if the episode daily and monthly variability factors should be included in calculating the option variability factors. One criteria that EPA used was that the daily and monthly variability factors should be greater than 1.0. A variability factor less than 1.0 would result in a unexpected result where the estimated 99th percentile would be less than the long-term average. This would be an indication that the estimate of $\hat{\sigma}$ (the log standard deviation) was unstable. A second criteria was that the daily variability factor had to be greater than the monthly variability factor. A third criteria was that not all of the sample-specific detection limits could exceed the values of the non-censored values. All the episode variability factors used for the limitations and standards met these criteria.

E.5 References

Aitchison, J. and J.A.C. Brown. 1963. *The Lognormal Distribution.* Cambridge University Press, New York.

Barakat, R. 1976. Sums of Independent Lognormally Distributed Random Variables. *Journal of the Optical Society of America* 66: 211-216.

Cohen, A. Clifford. 1976. Progressively Censored Sampling in the Three Parameter Log-Normal Distribution. *Technometrics* 18:99-103.

Crow, E.L. and K. Shimizu. 1988. *Lognormal Distributions: Theory and Applications*. Marcel Dekker, Inc., NY.

Kahn, H.D., and M.B. Rubin. 1989. Use of Statistical Methods in Industrial Water Pollution Control Regulations in the United States. *Environmental Monitoring and Assessment,* vol. 12:129-148.

Owen, W.J. and T.A. DeRouen. 1980. Estimation of the Mean for Lognormal Data Containing Zeroes and Left-Censored Values, with Applications to the Measurement of Worker Exposure to Air Contaminants. *Biometrics* 36:707-719.

U.S. Environmental Protection Agency. 2000. *Development Document for Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Point Source Category*. Volume I, Volume II. EPA 440/1-87/009.

APPENDIX F
ALTERNATIVE STATISTICAL METHODS

APPENDIX F: ALTERNATIVE STATISTICAL METHODS

This appendix describes statistical methods that EPA may consider for modeling the effluent data for developing the final limitations and standards for the concentrated aquatic animal production (CAAP) industry. A typical CAAP effluent data set from a sampling episode or self-monitoring episode (see Chapter 8 for a discussion of the data associated with these episodes) consists of a mixture of measured concentrations and values reported as being less than some sample-specific detection limit (e.g., <10 mg/L) or "non-detected." In statistical terms, measured concentrations are "non-censored" and non-detected values are "left-censored." The distinction between non-censored and left-censored measurements is often important in modeling the data and each model described in this appendix has different underlying assumptions about the physical processes that generate non-censored and left-censored measurements. For example, the modified delta-lognormal distribution assumes that they are generated from different processes and models the non-detected values using a delta distribution, while the censored lognormal distribution assumes that all observations (non-censored and non-detected) are regarded as random measurements generated from a common underlying lognormal distribution. In the censored lognormal model, non-detect measurements are treated as left-censored observations in the lognormal distribution.

Section F.1 provides a brief summary of the modified delta-lognormal distribution that was used for the proposal and is described in Appendix E. The remaining sections discuss another modification of delta-lognormal distribution, the censored lognormal distribution, the probability regression method for the lognormal distribution, and nonparametric methods. Before the final rule, EPA will evaluate the appropriateness of these models for the CAAP industry effluent data. EPA also will evaluate whether the predicted values are consistent with the observed effluent values.

F.1 MODIFIED DELTA-LOGNORMAL MODEL

For the proposed, EPA used the modified delta-lognormal distribution to model the effluent concentrations from the CAAP industry. As explained in Appendix E, this distribution models the data as a mixture of measurements that follow a lognormal distribution and non-detected measurements that occur with a certain probability (Aitchison and Brown (1963), Kahn and Rubin (1989), and U.S. EPA (1993)). By a modification to the delta portion of the distribution, this model also allows for the possibility that non-detected measurements can be observed at different sample-specific detection limits.

For some industries, different pollutant-generating mechanisms appear to act to produce non-censored and non-detected measurements at a facility. For example, non-detected measurements may indicate that the pollutant is not generated by a particular source or production practice, and non-censored values may be generated by different source, production, and/or wastewater treatment conditions. The modified delta-lognormal distribution is appropriate for such data sets because each data type (i.e., non-censored measurements and non-detected measurements) is modeled separately with different distributional properties. For the final rule, EPA will evaluate whether this assumption is appropriate for CAAP data.

F.2 ANOTHER MODIFICATION OF THE DELTA-LOGNORMAL MODEL

Another possible model for the CAAP effluent data is a further modification of the delta-lognormal distribution described in the previous section. This modification would incorporate left-censoring into the lognormal portion of the model while retaining the delta distribution for the non-detected measurements. This model would explicitly censor the lognormal distribution at some point, such as the minimum sample-specific detection limit observed in a data set. The lognormal distribution would be censored at this point because laboratory instruments would be incapable of measuring below that point and would be reported as non-detected values. Thus, non-censored values would be assumed to be observed only above this point. This modification is based upon an extension of the method developed by Moulton and Halsey (1995). EPA used a similar modification in developing the limitations for the pulp and paper industry (USEPA). Its implementation resulted in only minor differences from the values obtained from the model described in Section F.1.

F.3 CENSORED LOGNORMAL DISTRIBUTION

In a censored lognormal model (see Cohen, 1959), all observations (non-censored and non-detected) are regarded as random measurements generated from a common underlying lognormal distribution. Estimates of the mean, variance, and upper percentiles, used as a basis of the limitations, can be computed from the estimated best-fitting lognormal distribution. These estimates are similar to those derived under the modified delta-lognormal model, except that in Cohen's procedure non-detected measurements are treated merely as one type of censored sample, namely left-censored. Thus, it is assumed that non-detects, if the true concentration or mass amounts were measurable, would follow the same lognormal pattern as the rest of the data set.

F.4 PROBABILITY REGRESSION METHOD FOR THE LOGNORMAL DISTRIBUTION

The probability regression method assumes that the entire data set would follow a specific distributional model (e.g., the lognormal distribution) if concentrations of non-detected measurements could be observed. The basic idea behind the probability regression technique can be described by first considering the case with no censored measurements (for instance, a set of detected and precisely known observations). If it is assumed that the data were generated by an underlying lognormal distribution, then it would be expected that the logged values would plot on a probability plot in roughly a linear pattern when graphed against ordered quantiles from a standard normal distribution. In fact, it would be possible in this case to fit a linear regression to the points on the probability plot and determine the slope and intercept of the regression equation. The slope and intercept of this regression equation allow the estimation of an "optimal" set of parameters for fitting a specific lognormal density to the observed data. When the censored data are non-detects exhibiting multiple detection limits, and the set of detection limits overlaps the set of detected values, the desired ordering of the data is more difficult to construct. However, Helsel and Cohn (1988) adapt the simpler probability regression method with a single detection limit to the more general case of multiple detection limits and overlapping of non-censored and non-detected measurements. This adaptation orders the data in terms of conditional probabilities. EPA will evaluate whether an ordering of the non-detected values is appropriate for the CAAP effluent data.

F.5 NONPARAMETRIC METHODS

In contrast to the other statistical methods discussed in this appendix, nonparametric methods are not based on fitting a distribution to the data. The nonparametric estimate of the 99th percentile of an effluent concentration data set is the observed value that exceeds 99 percent of the data points. If a data set consists of fewer than 100 observations the best that can be done, using nonparametric methods, is to use the maximum value as an approximate nonparametric estimate of the 99th percentile, but this will underestimate the true value (in statistical expectation). Because most of the data sets analyzed in support of limitations development had fewer than 100 observations, it was prudent to adopt a parametric approach, such as the modified delta-lognormal distribution, to avoid underestimating the values used as a basis of the limitations. EPA will determine if these sample size constraints exist for the final rule.

F.6 REFERENCES

Aitchison, J. and J.A.C. Brown. 1963. *The Lognormal Distribution.* Cambridge University Press, NY.

Cohen, A.C., Jr. 1959. Simplified estimators for the normal distribution when samples are singly censored or truncated. *Technometrics*, vol. 1, pp. 217-237.

Helsel. D.R. and T.A. Cohn. 1988. Estimation of descriptive statistics for multiply censored water quality data. *Water Resources Research*, vol. 24, no. 12, pp. 1997-2004.

Kahn, H.D., and M.B. Rubin. 1989. Use of statistical methods in industrial water pollution control regulations in the United States. *Environmental Monitoring and Assessment*, vol. 12, pp. 129-148.

Moulton, L.H. and N.A. Halsey. 1995. A mixture model with detection limits for regression analysis of antibody response to vaccine. *Biometrics*, vol. 51, pp. 1197-1205.

U.S. Environmental Protection Agency (USEPA). 1993. *Statistical Support Document for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper, and Paperboard Point Source Category*. EPA 821-R-93-023. U.S. Environmental Protection Agency, Washington, DC.

APPENDIX G
UNIT COST MODEL AND FREQUENCY FACTOR RESULTS FOR MODEL FACILITIES

Table G-1. Unit Cost Model and Frequency Factor Results for Model Facilities: Option 1

Regulatory Option 1 Unit Costs and Frequency Factors										
Species	***Model***	***FM Capital ($)***	***FM O&M ($)***	***FM Frequency Factor***	***QZ Capital ($)***	***QZ O&M ($)***	***QZ Frequency Factor***	***SB Capital ($)***	***SB O&M ($)***	***SB Frequency Factor***
Trout-Food-size-Commercial-Flow-through	Medium	–	–	–	7,195.56	4,339.28	0.91	26,343.55	3,887.96	0.91
Trout-Food-size-Commercial-Flow-through	Large	–	–	–	53,367.07	28,974.66	1.00	286,015.67	5,461.58	1.00
Trout-Food-size-State-Flow-through	Medium	–	–	–	7,795.19	4,659.22	1.00	30,162.01	3,912.58	1.00
Trout-Food-size-State-Flow-through	Large	–	–	–	11,992.60	6,898.80	1.00	63,242.13	4,122.27	1.00
Trout-Stockers-Commercial-Flow-through	Medium	–	–	–	6,595.93	4,019.34	1.00	24,259.24	3,876.38	1.00
Trout-Stockers-Federal-Flow-through	Medium	–	–	–	7,195.56	4,339.28	0.57	26,285.19	3,887.48	0.57
Trout-Stockers-Federal-Flow-through	Large	–	–	–	29,381.87	16,177.06	0.50	157,030.04	4,685.71	0.50
Trout-Stockers-State-Flow-through	Medium	–	–	–	7,195.56	4,339.28	0.91	27,629.59	3,898.41	0.91
Trout-Stockers-State-Flow-through	Large	–	–	–	10,793.34	6,258.92	1.00	56,987.49	4,085.06	1.00
Trout-Stockers-Other-Flow-through	Medium	–	–	–	12,592.23	7,218.74	1.00	47,494.59	4,006.35	1.00
Trout-Stockers-Other-Flow-through	Large	–	–	–	10,193.71	5,938.98	1.00	54,874.86	4,074.18	1.00
Tilapia-Food-size Commercial-Flow-through	Medium	–	–	–	8,394.82	4,979.16	0.67	30,978.03	3,913.85	0.67
Tilapia-Food-size Commercial-Flow-through	Large	–	–	–	21,586.68	12,017.84	1.00	114,695.32	4,431.48	1.00
Tilapia-Food-size Commercial-Recirculating	Large	–	–	–	–	–	–	20,661.44	3,944.30	1.00
Striped Bass-Food-size Commercial-Flow-through	Medium	–	–	–	3,911.33	2,586.94	1.00	15,226.05	3,829.07	1.00
Striped Bass-Food-size Commercial-Recirculating	Large	–	–	–	–	–	–	72,246.56	4,331.27	1.00
Salmon-Food-size-Other-Flow-through	Large	–	–	–	50,368.92	27,374.96	1.00	270,766.77	5,372.23	1.00
Salmon-Food-size-Commercial-Net pen	Large	0	3,753.36	0.88	–	–	–	–	–	–

Note: FM = feed management; QZ = quiescent zone; SB = settling basin.

Regulatory Option 1 Unit Costs and Frequency Factors (continued)

Species	***Model***	***BMP Plan Capital ($)***	***BMP Plan O&M ($)***	***BMP Plan Frequency Factor***	***Monitoring Capital ($)***	***Monitoring O&M ($)***	***Monitoring Frequency Factor***
Trout-Food-size-Commercial-Flow-through	Medium	1,076.80	253.80	0.32	0.00	3,396.48	0.32
Trout-Food-size-Commercial-Flow-through	Large	1,076.80	253.80	1.00	0.00	3,396.48	1.00
Trout-Food-size-State-Flow-through	Medium	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Trout-Food-size-State-Flow-through	Large	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Trout-Stockers-Commercial-Flow-through	Medium	1,076.80	253.80	0.60	0.00	3,396.48	0.60
Trout-Stockers-Federal-Flow-through	Medium	1,076.80	253.80	0.14	0.00	3,396.48	0.14
Trout-Stockers-Federal-Flow-through	Large	1,076.80	253.80	0.50	0.00	3,396.48	0.50
Trout-Stockers-State-Flow-through	Medium	1,076.80	253.80	0.02	0.00	3,396.48	0.02
Trout-Stockers-State-Flow-through	Large	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Trout-Stockers-Other-Flow-through	Medium	1,076.80	253.80	1.00	0.00	3,396.48	1.00
Trout-Stockers-Other-Flow-through	Large	1,076.80	253.80	1.00	0.00	3,396.48	1.00
Tilapia-Food-size Commercial-Flow-through	Medium	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Tilapia-Food-size Commercial-Flow-through	Large	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Tilapia-Food-size Commercial-Recirculating	Large	1,076.80	253.80	0.40	0.00	3,396.48	0.40
Striped Bass-Food-size Commercial-Flow-through	Medium	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Striped Bass-Food-size Commercial-Recirculating	Large	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Salmon-Food-size-Other-Flow-through	Large	1,076.80	253.80	0.00	0.00	3,396.48	0.00
Salmon-Food-size-Commercial-Net pen	Large	1,076.80	253.80	0.13	–	–	–

Table G-2. Unit Cost Model and Frequency Factor Results for Model Facilities: Option 2

Species	***Model***	***Health and Chemical BMP Plan Capital ($)***	***Health and Chemical BMP Plan O&M ($)***	***Health and Chemical BMP Plan Frequency Factor***
Trout-Flow-through	Medium	1,076.80	253.80	0.00
Trout-Flow-through	Large	1,076.80	253.80	0.00
Trout-State-Flow-through	Medium	1,076.80	253.80	0.00
Trout-State-Flow-through	Large	1,076.80	253.80	0.00
Trout-Stockers-Flow-through	Medium	1,076.80	253.80	0.00
Trout-Stockers-Federal-Flow-through	Medium	1,076.80	253.80	0.00
Trout-Stockers-Federal-Flow-through	Large	1,076.80	253.80	0.00
Trout-Stockers-State-Flow-through	Medium	1,076.80	253.80	0.00
Trout-Stockers-State-Flow-through	Large	1,076.80	253.80	0.00
Trout-Stockers-Other-Flow-through	Medium	1,076.80	253.80	0.00
Trout-Stockers-Other-Flow-through	Large	1,076.80	253.80	0.00
Tilapia-Flow-through	Medium	1,076.80	253.80	0.00
Tilapia-Flow-through	Large	1,076.80	253.80	0.00
Tilapia-Recirculating	Large	1,076.80	253.80	0.00
Striped Bass-Flow-through	Medium	1,076.80	253.80	0.00
Striped Bass-Recirculating	Large	1,076.80	253.80	0.00
Salmon-Other-Flow-through	Large	1,076.80	253.80	0.00
Salmon-Net Pen	Large	1,076.80	253.80	0.00

Table G-3. Unit Cost Model and Frequency Factor Results for Model Facilities: Option 3

Regulatory Option 3 Unit Costs and Frequency Factors										
Species	***Model***	***SP Capital ($)***	***SP O&M ($)***	***SP Frequency Factor***	***Monitor Capital ($)***	***Monitor O&M ($)***	***Monitor Frequency Factor***	***AF Monitoring Capital ($)***	***AF Monitoring O&M($)***	***AF Frequency Factor***
Trout-Flow-through	Medium	8,052.91	1,861.32	0.09	–	–	–	–	–	–
Trout-Flow-through	Large	8,574.86	1,861.32	0.00	0.00	1,920.00	1.00	–	–	–
Trout-State-Flow-through	Medium	8,052.91	1,862.32	0.00	–	–	–	–	–	–
Trout-State-Flow-through	Large	8,052.91	1,861.32	0.00	0.00	1,920.00	0.00	–	–	–
Trout-Stockers-Flow through	Medium	8,052.91	1,861.32	0.00	–	–	–	–	–	–
Trout-Stockers-Federal-Flow-through	Medium	8,052.91	1,861.32	0.00	–	–	–	–	–	–
Trout-Stockers-Federal-Flow-through	Large	8,052.91	1,861.32	0.00	0.00	1,920.00	0.50	–	–	–
Trout-Stockers-State-Flow-through	Medium	8,052.91	1,861.32	0.05	–	–	–	–	–	–
Trout-Stockers-State-Flow-through	Large	8,052.91	1,831.32	0.00	0.00	1,920.00	0.00	–	–	–
Trout-Stockers-Other-Flow-Through	Medium	8,052.91	1,861.32	0.00	–	–	–	–	–	–
Trout-Stockers-Other-Flow-through	Large	8,052.91	1,861.32	0.00	0.00	1,920.00	1.00	–	–	–
Tilapia-Flow-through	Medium	8,052.91	1,861.32	0.00	–	–	–	–	–	–
Tilapia-Flow-through	Large	8,052.91	1,861.32	0.00	0.00	1,920.00	0.00	–	–	–
Tilapia-Recirculating	Large	8,052.91	1,861.32	0.40	0.00	1,920.00	0.40	–	–	–
Striped Bass-Flow-through	Medium	8,052.91	1,861.32	1.00	–	–	–	–	–	–
Striped Bass-Recirculating	Large	8,052.91	1,861.32	0.67	0.00	1,920.00	0.00	–	–	–
Salmon-Other-Flow-through	Large	8,574.86	1,861.32	0.00	0.00	1,920.00	0.00	–	–	–
Salmon-Net Pen	Large	–	–	–	–	–	–	10,000.00	3,828.42	0.38

Note: SP = solids polishing; AF = active feed.

Table G-4. Unit Cost Model and Frequency Factor Results for Alaska Salmon Flow-through Facilities: Option 1

Facility	*Harvest (lb/yr)*	*QZ Capital ($)*	*QZ O&M ($)*	*QZ Frequency Factor*	*SB Capital ($)*	*SB O&M ($)*	*SB Frequency Factor*
Facility 1	201,052	6,378.67	5,933.51	0	24,884.00	5,071.32	0
Facility 2	204,139	6,476.61	6,016.94	0	25,252.76	5,075.47	0
Facility 3	144,436	4,582.44	4,403.44	0	17,862.69	4,995.29	0
Facility 4	135,510	4,299.25	4,162.21	0	16,796.40	4,983.30	0
Facility 5	403,515	12,802.10	11,405.15	0	49,715.01	5,343.22	0
Facility 6	150,822	4,785.05	4,576.02	0	18,625.54	5,003.87	0
Facility 7	125,720	3,988.65	3,897.63	0	15,626.91	4,970.16	0
Facility 8	207,649	6,587.97	6,111.80	0	25,672.06	5,080.18	0
Facility 9	985,194	31,256.71	27,125.26	0	121,265.81	6,124.40	0
Facility 10	116,636	3,700.45	3,652.13	0	14,541.75	4,957.96	0
Facility 11	366,030	11,612.83	10,392.11	0	45,108.09	5,292.88	0
Facility 12	244,543	7,758.48	7,108.87	0	30,208.38	5,129.73	0
Facility 13	571,095	18,118.82	15,934.07	0	70,378.97	5,568.28	0
Facility 14	145,089	4,603.16	4,421.09	0	17,940.69	4,996.17	0
Facility 15	222,290	7,052.47	6,507.48	0	27,421.04	5,099.85	0
Facility 16	250,047	7,933.10	7,257.62	0	30,865.88	5,137.12	0
Facility 17	104,738	3,322.97	3,330.59	0	12,991.40	4,941.98	0
Facility 18	153,371	4,865.92	4,644.91	0	19,059.08	5,007.29	0

Note: QZ = quiescent zone; SB = settling basin.

Regulatory Option 1 Unit Costs and Frequency Factors (continued)							
Facility	***Harvest (lb/yr)***	***BMP Plan Capital ($)***	***BMP Plan O&M ($)***	***BMP Plan Frequency Factor***	***Monitoring Capital ($)***	***Monitoring O&M ($)***	***Monitoring Frequency Factor***
Facility 1	201,052	1,710.40	436.92	0	0	4,805.76	0
Facility 2	204,139	1,710.40	436.92	0	0	4,805.76	0
Facility 3	144,436	1,710.40	436.92	0	0	4,805.76	0
Facility 4	135,510	1,710.40	436.92	0	0	4,805.76	0
Facility 5	403,515	1,710.40	436.92	0	0	4,805.76	0
Facility 6	150,822	1,710.40	436.92	0	0	4,805.76	0
Facility 7	125,720	1,710.40	436.92	0	0	4,805.76	0
Facility 8	207,649	1,710.40	436.92	0	0	4,805.76	0
Facility 9	985,194	1,710.40	436.92	0	0	4,805.76	0
Facility 10	116,636	1,710.40	436.92	0	0	4,805.76	0
Facility 11	366,030	1,710.40	436.92	0	0	4,805.76	0
Facility 12	244,543	1,710.40	436.92	0	0	4,805.76	0
Facility 13	571,095	1,710.40	436.92	0	0	4,805.76	0
Facility 14	145,089	1,710.40	436.92	0	0	4,805.76	0
Facility 15	222,290	1,710.40	436.92	0	0	4,805.76	0
Facility 16	250,047	1,710.40	436.92	0	0	4,805.76	0
Facility 17	104,738	1,710.40	436.92	0	0	4,805.76	0
Facility 18	153,371	1,710.40	436.92	0	0	4,805.76	0

Table G-5. Unit Cost Model and Frequency Factor Results for Alaska Salmon Flow-through Facilities: Option 2

Facility	*Harvest (lb/yr)*	*BMP Plan Capital ($)*	*BMP Plan O&M ($)*	*BMP Plan Frequency Factor*
Facility 1	201,052	1,710.40	436.92	0
Facility 2	204,139	1,710.40	436.92	0
Facility 3	144,436	1,710.40	436.92	0
Facility 4	135,510	1,710.40	436.92	0
Facility 5	403,515	1,710.40	436.92	0
Facility 6	150,822	1,710.40	436.92	0
Facility 7	125,720	1,710.40	436.92	0
Facility 8	207,649	1,710.40	436.92	0
Facility 9	985,194	1,710.40	436.92	0
Facility 10	116,636	1,710.40	436.92	0
Facility 11	366,030	1,710.40	436.92	0
Facility 12	244,543	1,710.40	436.92	0
Facility 13	571,095	1,710.40	436.92	0
Facility 14	145,089	1,710.40	436.92	0
Facility 15	222,290	1,710.40	436.92	0
Facility 16	250,047	1,710.40	436.92	0
Facility 17	104,738	1,710.40	436.92	0
Facility 18	153,371	1,710.40	436.92	0

Table G-6. Unit Cost Model and Frequency Factor Results for Alaska Salmon Flow-through Facilities: Option 3

		Regulatory Option 3 Unit Costs and Frequency Factors					
Facility	***Harvest (lb/yr)***	***Solids Polishing Capital ($)***	***Solids Polishing O&M ($)***	***Solids Polishing Frequency Factor***	***Monitoring Capital ($)***	***Monitoring O&M ($)***	***Monitoring Frequency Factor***
Facility 1	201,052	8,052.91	2,320.48	0	0	1,920.00	0
Facility 2	204,139	8,052.91	2,320.48	0	0	1,920.00	0
Facility 3	144,436	8,052.91	2,320.48	0	0	1,920.00	0
Facility 4	135,510	8,052.91	2,320.48	0	0	1,920.00	0
Facility 5	403,515	8,052.91	2,320.48	0	0	1,920.00	0
Facility 6	150,822	8,052.91	2,320.48	0	0	1,920.00	0
Facility 7	125,720	8,052.91	2,320.48	0	0	1,920.00	0
Facility 8	207,649	8,052.91	2,320.48	0	0	1,920.00	0
Facility 9	985,194	8,052.91	2,320.48	0	0	1,920.00	0
Facility 10	116,636	8,052.91	2,320.48	0	0	1,920.00	0
Facility 11	366,030	8,052.91	2,320.48	0	0	1,920.00	0
Facility 12	244,543	8,052.91	2,320.48	0	0	1,920.00	0
Facility 13	571,095	8,052.91	2,320.48	0	0	1,920.00	0
Facility 14	145,089	8,052.91	2,320.48	0	0	1,920.00	0
Facility 15	222,290	8,052.91	2,320.48	0	0	1,920.00	0
Facility 16	250,047	8,052.91	2,320.48	0	0	1,920.00	0
Facility 17	104,738	8,052.91	2,320.48	0	0	1,920.00	0
Facility 18	153,371	8,052.91	2,320.48	0	0	1,920.00	0