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Aquaculture Waste Disposal Wells

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AQUACULTURE WASTE DISPOSAL WELLS

The U.S. Environmental Protection Agency (USEPA) conducted a study of Class V underground injection wells to develop background information the Agency can use to evaluate the risk that these wells pose to underground sources of drinking water (USDWs) and to determine whether additional federal regulation is warranted. The final report for this study, which is called the Class V Underground Injection Control (UIC) Study, consists of 23 volumes and five supporting appendices. Volume 1 provides an overview of the study methods, the USEPA UIC Program, and general findings. Volumes 2 through 23 present information summaries for each of the 23 categories of wells that were studied (Volume 21 covers 2 well categories). This volume, which is Volume 11, covers Class V aquaculture waste disposal wells.

1. SUMMARY

Methods employed for the controlled cultivation of aquatic organisms can vary substantially. Some aquaculture facilities use pens suspended in open water bodies, while others use systems that circulate water through tanks. Many aquaculture operations accumulate wastewater and sludge that requires removal. At dozens of such facilities in Hawaii and in several other states, this effluent is disposed via underground injection.

Injected aquaculture effluent includes fecal and other excretory wastes and uneaten aquaculture food. The primary chemical and physical constituents of these wastewaters are therefore nitrogen- and phosphorus-based nutrients and suspended and dissolved solids. The effluent may also contain bacteria pathogenic to humans and chemicals, pesticides, and/or aquaculture additives. However, the incidence and concentrations of human pathogenic bacteria, chemicals, pesticides, and additives in injectate is unknown. Information on aquaculture wastewater quality industry-wide is very limited, and wastewater properties are believed to vary greatly among different aquaculture operations. Available analytical data for aquaculture injectate and aquaculture effluent suggest that the concentrations of most parameters are generally below applicable standards. Contaminants that may exceed the standards under some circumstances include turbidity and possibly nitrite and nitrate. The secondary maximum contaminant level (MCL) for chloride is also exceeded in the wastewater from some seawater-based operations, but as long as these wastes are injected to saline aquifers, they pose no threat to USDWs.

The injection zone for aquaculture wastewater is characterized by relatively high porosity, as aquaculture wastewaters typically have significant suspended solids content. Seawater-based aquaculture operations in Hawaii inject wastewater into brackish or saline aquifers that flow seaward. Little information is available regarding other aquifers receiving aquaculture injectate.

No contamination incidents related to aquaculture wastewater disposal have been reported. Information about the threat of contamination posed by these wells is also inconclusive. For example, in Idaho, an aquaculture well is known to inject wastewater directly into an aquifer, but the quality of the aquifer, its status as a USDW, and the resulting impacts, are unknown. The subsurface disposal system (i.e., a leaching field) known to be in use by an aquaculture operation in Maryland is situated above a Type 1 (high quality) aquifer, but no impacts have been observed.

Aquaculture wells generally are not vulnerable to spills or illicit discharges. Most are located within private facilities and are not accessible to the public for unsupervised waste disposal. However, the potential exists for operators to dispose of harmful liquid wastes (e.g., waste aquaculture chemicals, or spent tank water with higher concentrations of chemicals used for temporary treatment of cultivated organisms) via aquaculture injection wells. No such cases have been reported.

According to the state and USEPA Regional survey conducted for this study, a total of 56 documented Class V aquaculture waste disposal wells exist in the U.S. The great majority occur in Hawaii (51 wells, or 93 percent). The remaining documented wells are in Wyoming (2 wells), Idaho (1 well), New York (1 well), and Maryland (1 well). In addition to these documented wells, as many as 50 additional wells are estimated to exist in California. Thus, the true number of aquaculture waste disposal wells in the U.S. is likely to approach 100. Given that the value of U.S. aquaculture production has grown by 5 to 10 percent per year over the past decade, and that the aquaculture industry remains the fastest growing segment of U.S. agriculture, there is some possibility that the number of Class V aquaculture waste disposal wells will increase.

Programs to manage Class V aquaculture waste disposal wells vary between the states with documented or estimated wells:

- In California, USEPA Region 9 directly implements the Class V UIC program. In addition, under the California Water Quality Control Act, nine Regional Water Quality Control Boards coordinate and advance water quality in each region. These Boards may prescribe discharge requirements for discharges into the waters of the state under regional water quality control plans.

- In Hawaii, USEPA Region 9 directly implements the Class V UIC program. In addition, aquaculture waste disposal wells are authorized by individual permits issued by the state Department of Health. Class V wells are subject to siting requirements, and prohibited from operating in a manner that allows the movement of contaminants into a USDW.

- In Idaho, which is a Primacy State, wells greater than 18 feet deep are individually permitted, while shallower wells are authorized by rule. The state has enacted an antidegradation policy to maintain the existing uses of all ground water.

- Maryland is also a Primacy State. In addition to the state's UIC Class V program, the state's pollution discharge elimination system can require permits for discharges into ground water. Individual permits are required for any discharge of pollutants to ground water, for any industrial discharge of wastewater to a well or septic system, for any septic system with 5,000 gpd or greater capacity, or for any well that injects fluid directly into a USDW. County health departments, as well as the state Department of the Environment, can oversee aquaculture waste discharge wells.

- In New York, the Class V UIC program is directly implemented by USEPA Region 2. The state also implements a State Pollution Discharge Elimination System (SPDES) to protect the waters of the state, which include ground waters. Aquaculture waste disposal wells can be required to obtain an SPDES permit for discharges into ground water.

C Wyoming is a Primacy State and aquaculture wells are covered under a general permit under the state's Class V UIC program. The permit covers a class of operators, all of whom inject similar types of fluids for similar purposes, and requires somewhat less information to be submitted by the applicant than is required by an individual permit. The well must satisfy specific construction and operating requirements (e.g., pretreatment of wastewater).

2. INTRODUCTION

The term "aquaculture" has been defined in many different ways. In addition to the international definition used by the United Nations (see text box), the term has taken a number of definitions in the United States. According to the National Aquaculture Act of 1980, 16 U.S.C. 2801, the term "aquaculture" means the propagation and rearing of aquatic species in controlled or selected environments. USEPA (1987) defines it simply as the active cultivation of marine and freshwater aquatic organisms under controlled conditions, while Buck (1999) defines the term to include both the farming and the husbandry of fish, shellfish, and other aquatic animals and plants.

What is Aquaculture?

According to the Food and Agriculture Organization (FAO) of the United Nations, the term "aquaculture" is defined as "the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated" (FAO, 1997).

These definitions encompass a broad range of organisms and a wide variety of production systems and facilities. Aquaculture operations across the U.S. produce more than 100 species of aquatic organisms at different life stages, although about 10 species of shellfish and finfish dominate the industry (Goldburg and Triplett, 1997). These operations utilize salt, brackish, and/or fresh waters. As the purpose of the facility can also vary, this study considers those facilities that propagate aquatic organisms for commercial purposes (e.g., for sale as food) as well as those that rear aquatic organisms for research and/or educational purposes (e.g., public display).

A common attribute of all aquaculture systems is the use of water as the medium for cultivation. Aquaculture systems provide a constant supply of sufficiently clean and oxygenated water to support the cultivated organisms, and also to carry away deoxygenated water and wastes. Systems that hold organisms within open, natural water bodies (suspended cages, net pens, or racks) rely on natural water circulation or dispersion to accomplish this water “turnover.” Wastes released from these systems are not collected or managed, and this type of aquaculture operation is therefore beyond the scope of this study. By comparison, pond culture, recirculating systems (i.e., closed systems where some or all of the water is filtered and reused), and single-pass systems (i.e., channels or troughs with water flowing from one end to the other) are required to manage the supply and condition of water in the system, including the removal and management of wastes (largely consisting of wastewater). These types of aquaculture systems are considered in this study. Specifically, this study focuses on aquaculture operations that manage at least a portion of their wastewater by releasing it into Class V underground injection wells (see below), and more broadly on aquaculture operations that collect and manage their wastewater, and therefore may consider underground injection as a means of wastewater management.

Aquaculture wastewater parameters are as varied as the types of aquaculture systems in operation. Wastewater effluent consist primarily of uneaten food and excretory wastes from cultivated organisms. Aquaculture wastewater effluent can also include a variety of chemicals, pesticides, and/or feed additives that are added to systems to condition the water, medicate the cultivated organisms, control pests, or aid growth patterns.

Many aquaculture systems employ a constant through-flow of water. These systems typically generate wastewater at a relatively high and constant rate, with relatively low contamination levels. Systems that filter, re-oxygenate, and recycle water typically generate more concentrated wastewater and sludges (from the filtration process), but at lower or intermittent rates. Most tank-based aquaculture systems also often have intermittent discharges of concentrated wastewater during cleaning and harvesting operations.

All of these wastewater types can be, and in some cases are, injected into Class V underground injection wells. Available data indicate, however, that only a very few aquaculture operations (roughly 100 nationwide) currently dispose of wastewater by underground injection.

According to the existing underground injection control (UIC) regulations in 40 CFR 146.5(e)(12), “wells used to inject fluids that have undergone chemical alteration during...aquaculture...” are classified as Class V injection wells. For purposes of this study, aquaculture waste disposal wells include wells that drain or inject waste fluids from aquacultural operations into the subsurface. This includes wastewater drained directly from tanks or ponds, as well as wastewater from filtration systems, sludge removal processes, and cleaning operations. As currently defined in the UIC regulations (40 CFR 144.3), a “well means a bored, drilled or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension.” Therefore, any hole that is deeper than it is wide or long qualifies as a well. In the case of aquaculture waste disposal wells, this includes holes drilled and cased with pipe, as well as “infiltration galleries” consisting of one or more vertical pipes leading to an array of horizontal, perforated pipes laid below the ground surface, designed to release wastewater underground. Each of the vertical pipes in such a system, individually or in a series, is considered an injection well subject to UIC authorities (Elder and Lowrance, 1992).

3. PREVALENCE OF WELLS

For this study, data on the number of Class V aquaculture waste disposal wells were collected through a survey of state and USEPA Regional UIC Programs. The survey methods are summarized in Section 4 of Volume 1 of the Class V Study. Table 1 lists the number of Class V aquaculture waste disposal wells in each state, as determined from this survey. The table includes the documented number and estimated number of wells in each state, along with the source and basis for any estimate, when noted by the survey respondents. If a state is not listed in Table 1, it means that the UIC Program responsible for that state indicated in its survey response that it did not have any Class V aquaculture waste disposal wells.

As shown in Table 1, the available inventory information indicates that there are a total of 56 documented Class V aquaculture waste disposal wells in the U.S. Of these, 51 are in Hawaii, two are in Wyoming, and Idaho, Maryland, and New York have one documented well each. In addition to these documented wells, State of California and USEPA Region 9 officials estimate that there may be as many as 50 aquaculture waste disposal wells in California. Therefore, the best estimate indicates that fewer than 106 wells currently exist in the U.S.

Currently, Oregon has no registered Class V aquaculture waste disposal wells, but it is possible that some may exist at federal- and/or state-operated facilities and at one coastal aquarium facility. It is likely that the State of Oregon Department of Environmental Quality will register some Class V aquaculture facilities in the future (Priest, 1999).

Aquaculture is the fastest-growing segment of U.S. agriculture (Holeck et al., 1998). The National Marine Fisheries Service estimates that in 1997, the most recent year available, aquaculture production totaled almost 934 million dollars (NMFS, 1999). The value of U.S. aquaculture production has grown by roughly 5 percent to 10 percent per year over the past decade. As the industry continues to grow, it is possible that additional aquaculture operations will consider underground injection as a means of disposing at least a portion of their wastewater, although injection wells have proven to be a relatively uncommon means of waste disposal in the aquaculture industry to date. Several industry experts believe that it is unlikely that additional injection wells will be used in the future due to high regulatory and construction costs and a loss of a potentially valuable income-producing resource (i.e., nutrients from the effluent) (Castle, 1999; Jensen, 1999).

Table 1. Inventory of Aquaculture Wells in the U.S.

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
USEPA Region 1 -- None			
USEPA Region 2			
NY	1	1	N/A
USEPA Region 3			
MD	1	1	N/A
USEPA Region 4 -- None			
USEPA Region 5 -- None			
USEPA Region 6 -- None			
USEPA Region 7 -- None			
USEPA Region 8			
WY	2	2	Best professional judgement.
USEPA Region 9			
CA	0	< 50	Based on anecdotal information.
HI	51	51	N/A
USEPA Region 10			
ID	1	1	N/A
All USEPA Regions			
All States	56	< 106	Total estimated number counts the documented number when the estimate is NR.

[1] Unless otherwise noted, the best professional judgement is that of the state or USEPA Regional staff completing the survey questionnaire.

N/A Not available.

4. WASTEWATER CHARACTERISTICS AND INJECTION PRACTICES

4.1 Injectate Characteristics

Wastewater and injectate characteristics from aquaculture operations can be examined from two standpoints: (1) the known characteristics of injectate at the relatively few aquaculture operations now known to inject wastes into Class V wells; and (2) more general characteristics of aquaculture wastewater, describing the types of wastewaters that could potentially be injected in Class V wells if additional aquaculture operations elect this means of waste disposal as the domestic aquaculture industry grows. However, as discussed earlier in Section 3, many industry experts believe that this means of disposal will not become more widespread in the future.

The principal sources of contaminants in aquaculture effluent are unconsumed feed, excreta, and possibly chemical additives. Therefore, the principal contaminants in aquaculture effluent are nutrients from decomposing feed and excreta: nitrate, nitrite, ammonia, other nitrogen compounds, and phosphate and other forms of phosphorous. Other key physical/chemical parameters of aquaculture effluent include suspended and dissolved solids, biochemical oxygen demand (BOD), and low oxygen levels. Aquaculture effluents have been shown to contain microbial contamination, including human pathogens. Aquaculture operations also utilize antibiotics to control diseases; pesticides to control parasites, algae, and other pests; hormones to induce spawning; anesthetics to immobilize fish during transport and handling; and pigments, vitamins, and minerals to promote rapid growth and desired qualities in the cultivated organisms (Goldburg and Triplett, 1997). However, while these chemicals, pesticides, and feed additives may possibly be present in aquaculture effluent, little data exist on either their presence or, if present, their concentrations. Moreover, little evidence has been found to indicate problems from using approved compounds in their prescribed manner.

4.1.1 Injectate Data at Existing Wells

Data characterizing injectate at known Class V aquaculture waste disposal wells are limited. As outlined in Section 3, the existence of documented wells is limited to five states (HI, MD, ID, WY, NY) and wells are also believed to exist in an additional state (CA). Injectate data are available only for wells in Hawaii, Idaho, and Maryland, and are summarized below.

The Hawaii Aquaculture Effluent Discharge Program compiled a report in 1990 that describes a survey conducted from December 1988 to June 1989 of eleven Hawaiian aquaculture facilities that were injecting wastewater into Class V wells. Injectate quality parameters measured in the survey were dissolved nutrients, total nutrients, pigments, and suspended solids. Data from this survey are summarized in Table 2.

Injectate characteristics data provided to the Hawaii Department of Health by Sea Life Park in Waimanalo, Ouahu, are listed in Table 3. Sea Life Park operates 19 of Hawaii’s 51 documented Class V aquaculture waste disposal wells (Uehara, 1999). This operation and other similar facilities fall within the broad definition of aquaculture given earlier (see Section 2). In addition, Sea Life Park is considered to be an aquaculture facility by the Hawaii Department of Health UIC Program, and since it disposes of aquaculture wastewater via underground injection, it is included in this volume. Data in Table 3 are for samples at four injection wells, analyzed in December 1998. According to the Hawaii Department of Health UIC Program, chemicals are generally not used in aquaculture in Hawaii, except that Sea Life Park uses small amounts of chlorine as a disinfectant for mammal tank wastewater (Uehara, 1999).

Table 2. Aquaculture Injectate Characteristics, Hawaii (mg/l except where noted)

Parameter	Freshwater Fish Farm	Freshwater Prawn Farm	Marine Fish Farm	Marine Shrimp Farm
Dissolved Nutrients				
Nitrate and Nitrite	0.001 - 0.83	0.0043 - 0.52	0.0035 - 0.98	0.0038 - 0.5
Ammonia	0.0082 - 0.5	0.0042 - 0.2	0.007 - 0.7	0.003 - 1.2
Phosphate	0.008 - 0.11	0.007 - 0.055	0.014 - 0.32	0.006 - 0.51
Total Nutrients				
Total Nitrogen	0.0047 - 1.5	0.33 - 1.82	0.0015 - 1.62	0.09 - 1.7
Total Phosphorus	0.062 - 2.2	0.14 - 1.0	0.02 - 0.5	0.03 - 1.5
Pigments				
Chlorophyll	0.001 - 5.0	0.1 - 1.0	0.001 - 0.18	0.003 - 1.1
Pheopigment	0.001 - 0.25	0.003 - 0.18	0.001 - 0.04	0.002 - 0.16
Suspended Solids				
Turbidity (NTU)	1 - 150	1.6 - 62	1 - 9.9	1.8 - 42
Total Filterable Solids	1.8 - 610	38 - 400	1.3 - 75	4.1 - 160
Ash-free Dry Weight	1 - 500,000	50 - 500	1 - 100	3 - 100

Source: Hawaii Aquaculture Effluent Discharge Program, 1990.

Table 3. Aquaculture Injectate Characteristics, Sea Life Park, Hawaii

Parameter	Average[1]	Range[1]
Ammonia (NH_4^+) (mg/l)	0.22	0.09 - 0.45
Nitrate & nitrite (mg/l)	1.46	1.31 - 1.75
Total nitrogen (mg/l)	2.45	1.45 - 3.48
Total phosphorus (mg/l)	0.22	0.18 - 0.31
Oil and grease (mg/l)	<10.0	All samples <10.0
Dissolved oxygen (mg/l)	6.33	6.14 - 6.48
pH	7.61	7.59 - 7.65
Temperature (°C)	25.9	25.9 - 26.0
Total coliform (colonies/100 ml)	-	12 - TNTC[2]
BOD_5 (mg/l)	<1.0	All samples <1.0
Total residual chlorine (mg/l)	None detected	None detected
Total suspended solids (mg/l)	3.35	2.86 - 4.28
Total dissolved solids (mg/l)	38,150	36,450 - 38,950
Turbidity (NTU)	0.28	0.21-0.33
Chloride (mg/l)	18,475	18,400 - 18,500

[1] Average and range for one sample at each of four wells.
[2] Too numerous to count.

Source: Uehara, 1999.

The single documented aquaculture injection well in Idaho, the Ten Springs Fish Farm, injects only a portion of its raceway[1] effluent water, which is regulated by a National Pollution Discharge Elimination System (NPDES) discharge permit, after it has been allowed to settle in a settling pond. Characteristics of the settling pond effluent, as it was injected in a nine-month span from 1992-1993, are presented in Table 4.

Information on the injectate at McGill Farms, the single aquaculture operation that injects wastes into a Class V well in Maryland, was provided by state and county officials (Eisner, 1999, and Browning, 1999, respectively). Effluents from the operation consist of wastewater and sludge from a biofilter process as well as water and sludge from the tanks themselves. Characteristics of the biofilter liquid effluent, as well as the sludge (fecal material), that is sent to the disposal system (similar in design to a septic system with septic tanks and leaching fields) are presented in Table 5 below.

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[1] A series of chambers through which water flows continuously.

Table 4. Aquaculture Injectate Characteristics, Ten Springs Fish Farm, ID (mg/l)

Parameter	Average[1]	Range[1]
Total suspended solids	-	none detected - 2.0
Nitrate N	0.91	0.64 - 1.34
Ammonia N	0.23	0.01 - 0.37
Kjeldahl N	0.58	0.30 - 1.02
Total Phosphorus	0.08	0.05 -0.14

[1] Data from 9 samples taken monthly from 12/92 through 8/93. Nitrogen and phosphorous parameters not analyzed in 2/93.

Source: Anderson, 1999.

Table 5. Characteristics of Effluent Sent to Disposal System, McGill Farms, MD (mg/l)

Parameter	Biofilter Effluent		Fecal Material
	1/10/98 Sample	2/3/98 Sample	12/24/97 Sample
Nitrate	--	--	130
Total Kjeldahl N	22.4	--	90.4
Ammonia	--	--	3.02
Total phosphorus	--	--	2.7
Suspended solids	355	510	1,760
BOD	169	285	1,241
Orthophosphorus	--	--	2.4

Source: Eisner, 1999.

It is apparent that the nutrient content of both biofilter effluent and solid wastes from McGill Farms are considerably higher than that of effluents reported for aquaculture operations in Hawaii and Idaho. However, at this Maryland operation, the wastes concentrated by the filtration process are partially removed and broken down in the septic tanks and then the supernatant is injected underground. The concentration of contaminants in the supernatant/ injectate from this system has not been analyzed, but can be assumed to be considerably lower than the concentrations presented in Table 5 (which shows the characteristics of the waste before it is sent to the septic system) because nutrients would be at least partially contained in or adhered to solids in the sludge. The State of Maryland authorities expressed concern that the McGill Farms injectate may contain bacteriological contamination, but data on the bacteriological content of the operations wastes are not available (Eisner, 1999). There were no plans to use chemical additives at McGill Farms at the time of application for a state ground water permit (Eisner, 1999).

Table 6 presents a comparison of the known parameters in documented aquaculture injectate to existing drinking water standards (MCLs) and health advisory levels (HALs). Many of the primary constituents of aquaculture effluent (phosphorous compounds, BOD, suspended solids) are not of direct concern from the standpoint of human toxicity, and drinking water standards or HALs have not been established for them.

Table 6. Comparison of Aquaculture Injectate Parameters to Drinking Water Standards and Health Advisory Levels

Constituent	Primary Drinking Water Standards and Health Advisory Levels			Nearest Value or Exceedence in Known Injectate (mg/l except where noted)	Operation
	Primary MCL (mg/l except where noted)	Secondary MCL (mg/l except where noted)	HAL-Noncancer Lifetime (mg/l)		
Ammonia			30 (draft advisory)	1.2	Marine Shrimp Farm, HI
Nitrate (as N)	10			1.34	Ten Springs Farm, ID
Nitrite (as N)	1			-	-
Nitrate and Nitrite (as N)	10			1.75	Sea Life Park, HI
Total dissolved solids		500		39	Sea Life Park, HI
pH (pH units)		6.5 - 8.5		7.59 - 7.65	Sea Life Park, HI
Turbidity (NTU)	0.5 - 1.0			150	Freshwater fish farm, HI
Chloride		250		18,500	Sea Life Park, HI
Total coliform (colonies/100 ml)	repeated detection[1]			12 - TNTC[2]	Sea Life Park, HI

[1] No more than 5.0 percent of samples collected during a month may be positive for coliform.

[2] Too numerous to count.

Source for standards and advisories: USEPA, 1999.

Based on the data presented in this section and in Table 6 for known injectate, concentrations of contaminants in unconcentrated aquaculture effluent are generally well within the established MCLs. There are a few exceptions, however. Of the primary aquaculture effluent constituents for which drinking water standards and advisories have been established (i.e., nitrogen compounds, total dissolved solids, pH, turbidity, and chloride), the values for chloride, turbidity, and possibly nitrate and nitrite (see explanation below) are exceeded according to current injectate data.

Chloride concentrations are well above the secondary MCL in the injectate from Sea Life Park (HI). This is of no significance, however, with respect to threats to USDWs or human health. The Sea Life Park operations use sea water, which naturally has very high chloride concentrations. Wastewater from Sea Life Park is injected into a saline aquifer that flows seaward, and is believed to pose no threat to USDWs. Chloride would only be of concern for any future sea or brackish water-based aquaculture operations that plan to inject their effluent in locations where they can affect USDWs. No aquaculture operations are known to do so at present.

Table 6 indicates that the established performance standard for turbidity is exceeded by the effluent from one aquaculture operation known to inject waste into Class V wells (i.e., the fresh water fish farm monitored by the Hawaii Aquaculture Effluent Discharge Program in 1990; see Table 2). While turbidity does not have direct human health effects, the primary MCL for turbidity has been established because turbidity can interfere with disinfection and can provide a medium for microbial growth.

The MCL for nitrate is exceeded in effluent from the McGill Farms (MD) operation (Table 5), but as previously noted, this effluent passes through a septic tank, where settling and some digestion and breakdown of contaminants typically occurs, prior to injection. Only the supernatant from the septic tank is injected into the subsurface disposal well. The concentration of nitrate in the supernatant/injectate is unknown. It is probably well below the concentration found in the raw effluent prior to entry into the septic tank (i.e., well below the concentrations shown in Table 5), but may nevertheless exceed the nitrate MCL. All other nitrate concentrations reported for Class V aquaculture injectate are below the MCL.

Although the data for aquaculture injectate presented in this section do not provide information on nitrite concentrations, effluent data from other aquaculture operations (not injecting wastes into wells) suggest that effluent from certain types of high-intensity operations (e.g., high-density shrimp farms) can contain nitrite at levels approaching the established MCL (Samocha and Lawrence, 1995). Thus nitrite concentrations are of possible concern for any future, high-intensity aquaculture operations planning to dispose of effluent via underground injection.

4.1.2 General Characteristics of Aquaculture Effluent

As the foregoing data suggest, wastewaters from various aquaculture operations generally share a common list of primary constituents: nitrogen- and phosphorous-based nutrients, and suspended and dissolved solids. Effluent quality data for the industry as a whole are limited. Moreover, the concentrations of these constituents in effluent probably vary greatly among different aquaculture operations, depending on a number of factors such as: water management systems (i.e., flow-through or recirculating); wastewater management systems (whether treatment or settling is applied to effluents); whether low-intensity or high-intensity aquaculture is practiced; the type and size of organisms raised; feeding efficiency; and other factors.

Bacteria are additional constituents of concern in aquaculture effluent. Fish wastes can contain bacteria that are known human pathogens and thus it is possible that aquaculture injectate may contain pathogenic bacteria. However, adequate data are not available to fully characterize the threat to USDWs and humans. Table 7 lists pathogenic bacteria found in fish and wastewater at aquaculture operations. The likelihood of such bacteria being present in wastewater, and the particular bacterial species likely to be present, varies depending on the type of aquacultural operation and species cultivated.

Table 7. Human Pathogenic Bacteria Found in Fish and Water at Aquaculture Operations

Pathogen	Possible Effect on Humans	Infection Route
Salmonella sp.	Food poisoning	Ingestion
Vibrio parahaemolyticuys	Food poisoning	Ingestion
Campilobacter jejuni	Gastroenteritis	Ingestion
Aeromonas hydrophila	Diarrhea/septacaemia	Ingestion
Plesiomonas shigelloides	Gastroenteritis	Ingestion
Edwardsiella tarda	Diarrhea	Ingestion
Pseudomonas aeruginosa	Wound Infection	Dermal
Pseudomonas fluorescens	Wound Infection	Dermal
Mycobacterium fortuitum	Mycobacteriosis	Dermal
Mycobacterium marinum	Mycobacteriosis	Dermal
Erysipelothrix rhusiopathiae	Erysipeloid	Dermal
Leptospira interrogans	Leptospirosis	Dermal

Source: Austin and Austin, 1989 (as cited in Smith et al., 1994).

A single set of data is available indicating microbial content in aquaculture injectate. All samples of injectate at Sea Life Park (HI) had coliform bacteria present (see Tables 3 and 6). This does not provide a useful indication of the possible presence of microbial pathogens in all types of aquaculture injectate, however. Sea Life Park raises marine mammals (for display purposes), and the microbial content in the effluent from this operation is probably very different from that of the great majority of aquaculture operations that raise non-mammal species for food.

Similarly, the types of chemicals, pesticides, and additives used in aquaculture are well known, but their incidence and concentrations in aquaculture effluents are not well quantified for the industry as a whole. The use and rate of application of these materials varies significantly and depends on factors such as the species raised, culture intensity (e.g., organism density), water quality, and operation type. Thus, the incidence and concentration of these materials in wastewaters is expected to vary considerably.

Three antibiotics are approved for use in U.S. aquaculture: oxytetracycline, sulfadimethoxine-ormetoprim, and sulfamerazine. However, the Federal Drug Administration's (FDA) new drug-use regulations allow other antibiotics and other drugs to be used under certain specified and controlled conditions (USFDA, 1996). FDA regulations include certification of proper drug usage and drug residue testing (FDA also requires an environmental impact review prior to drug approval). The approved drugs can be used only for certain fish species, and withdrawal times prior to harvest are specified on drug labels (USFDA, 1998). These regulations reduce the likelihood that these drugs will be present in aquaculture effluent at levels toxic to humans. However, as these regulations are focused on concentrations of drugs in the edible product, they can not be relied upon to maintain the concentration of drugs in wastewater within drinking water standards.

Fish hormones are sometimes used to induce maturation, spawning, and sex reversal for fish in hatcheries. FDA-approved color additives, carotenoids (also found naturally in many vegetables), may be fed to farmed salmon and trout to produce a pink/orange flesh that consumers prefer. Vitamins and minerals may also be added to feed to fulfill fish nutrition requirements (Goldburg and Triplet, 1997). Drugs approved by FDA for use in aquaculture, as well as drugs of low regulatory priority at FDA, are listed in Attachment A of this volume.

USEPA regulations allow the use of numerous herbicides, algaecides, and fish toxins (not necessarily common) in aquaculture systems where fish are raised for food. For example, fungicides may be used to ensure the healthy development of fish eggs. The USEPA-approved algaecides, herbicides, and other pesticides are also listed in Attachment A of this volume.

Finally, veterinary biologics (e.g., vaccines) are used in aquaculture for the prevention, diagnosis, and treatment of animal diseases. Preventive and therapeutic veterinary biologics act on or in concert with the body's immune system to provide or enhance resistance to disease. Diagnostic veterinary biologics are used to detect the presence of a disease organism or diseased cells as well as to detect immunity in the fish against disease organisms. The use of biologics in aquaculture is regulated by USDA’s Animal and Plant Health Inspection Service. Biologics approved by USDA for use in aquaculture are also listed in Attachment A of this volume.

The FDA-, USDA-, and USEPA-regulated chemicals listed in Attachment A are not necessarily present in aquaculture injectate. For example, some of the chemicals may not be used in closed systems, or may be applied in a manner preventing them from being in wastewater (i.e., they may degrade and break down before reaching the effluent). The herbicides listed in Attachment A that are used for weed control are generally used in large water bodies supporting open aquaculture operations that do not collect or manage wastes. These herbicides are therefore outside the scope of concern for aquaculture waste disposal wells.

Drugs and pesticides regulated by FDA and USEPA that are likely to be present in the effluent of some aquaculture operations, and could conceivably be present in current and future aquaculture injectate, are summarized in Table 8 below.

Table 8. Possible Chemical Contaminants in Aquaculture Effluent

FDA-Approved Drugs

Used as additives to tank water (likely to be in effluent in some operations):

- Tricaine methanesulfonate
- Formalin
- Oxytetracycline
- Sulfadimethoxine and ormetoprim
- Sulfamerizine

Used as solutions into which fish are dipped briefly (may be disposed of via wastewater disposal system):

- Acetic acid
- Calcium oxide
- Fuller's earth
- Magnesium sulfate
- Papain
- Povidone iodine compounds
- Sodium bicarbonate
- Sodium sulfite
- Urea
- Tannic acid

Drugs of Low Regulatory Priority for FDA Used in Aquaculture

Generally used as additives to tank water (could be present in effluent in some operations):

- Calcium chloride
- Hydrogen Peroxide
- Potassium chloride
- Sodium chloride

USEPA-Registered Pesticides For Aquaculture

Algaecides, generally added to tank water (likely to be present in effluent of some operations, but in instances of high BOD, copper compounds are likely to be complexed with suspended organics, and thus may become biologically unavailable):

- Chelated copper
- Copper (inorganic compounds)
- Elemental copper
- Copper sulfate pentahydrate
- Endothall

Herbicides, possibly used as additives to some tanks (may be present in the effluent from some operations):

- Acid blue and acid yellow
- Dichlobenil
- Diquat dibromide
- Glyphosate

Fish toxins, generally added to tank water (likely to be present periodically in effluent of some operations but not likely in tank or raceway systems):

- Antimycin
- Rotenone

As is the case with bacteriological contamination, however, data adequate to quantify the incidence and concentrations of the above materials in aquaculture effluent on an industry-wide basis are not available. The presence and concentration of these chemicals and biologics is expected to vary greatly from operation to operation, and from one period to another within individual operations. High concentrations of some chemicals used in aquaculture may be toxic to humans. However, the use of these materials is regulated to ensure safety of the aquaculture product, and this regulation may also ensure that concentrations of these materials in aquaculture waters and effluents are safe.

Primary drinking water standards have been established for four of the materials listed in Table 8, and a draft health advisory has been issued for one additional drug. These standards and the advisory are presented in Table 9. These constituents, since they are approved for use in aquaculture, could conceivably pose a threat to human health if introduced into USDWs in concentrations above these thresholds. However, adequate data are not available to estimate the likelihood of such contamination.

Table 9. Drinking Water Standards for Chemicals Used in Aquaculture

	Primary Standards		Health Advisory Levels For 70-kg Adult			
Chemicals/ Pesticides	**Regulatory Status**	**MCL (mg/l)**	**Status**	**Noncancer Lifetime (mg/l)**	**mg/l at 10^{-4} Cancer Risk**	**Cancer Group[1]**
Copper	Final	1.3	-	-	-	D
Diquat	Final	0.02	-	0.02	-	D
Endothall	Final	0.1	Final	0.1	-	D
Formaldehyde[2]	-	-	Draft	1	-	B1[3]
Glyphosate	Final	0.7	Final	0.7	-	E

[1] The categorization of cancer group according to the carcinogenic potentials of chemicals:

B1 -	probable human carcinogen, based on limited evidence in humans, and sufficient evidence in animals.
D -	inadequate or no human and animal evidence of carcinogenicity.
E -	no evidence of carcinogenicity in at least two adequate animal tests in different species or in adequate epidemiologic and animal studies.

[2] The active drug used in aquaculture is formalin, an aqueous solution of formaldehyde.
[3] Carcinogenicity based on inhalation exposure.

Source: USEPA, 1990.

4.2 Well Characteristics

4.2.1 Design Features

Specific design features of aquaculture waste disposal wells vary by site in order to account for local hydrogeologic conditions. However, based on currently available inventory data, two well types are most frequently used in the U.S.: vertical cased wells and shallow subsurface disposal systems.

Vertical cased wells are more numerous, and consist of a hollow casing installed vertically into the ground. The well casing is impermeable down to a specified depth, below which the casing is perforated to allow fluids to diffuse into the surrounding stratum or aquifer. The majority of case wells in use are less than 100 feet in depth; these usually have a diameter of approximately 8 inches. However, some are drilled to a depth of over 100 feet, and are typically 12 to 20 inches in diameter.

The majority of the injection wells in Hawaii are shallow cased wells with concrete walls (for design details, see USEPA, 1987). The injection well at Ten Springs Fish Farm in Idaho is a deep cased well with a 12-inch diameter drill hole and a depth of 180 feet. It is cased with 5-mm steel and sealed at the top with a ¼-inch screen.

A shallow subsurface disposal system is in use at McGill Farms in Maryland. This system is essentially a standard septic system with leaching field. Classified as a Class V injection well under the ground water permit program of the Maryland Department of the Environment, this system consists of two septic tanks, from which drain pipes run underground to perforated pipes lain in subsurface trenches filled with gravel. The septic tanks are constructed of concrete and each has a capacity of 1,500 gallons.

Although no further information was available on the McGill Farms system, Hartford County Health Department (HCHD) staff indicated that this system conforms in design to standard septic systems in the county (Browning, 1999). According to HCHD regulations for such systems, the wastewater from the septic tanks is distributed via a distribution box to a series of pipes buried in trenches. The trenches surrounding the pipes are typically between 35 and 100 feet long, 2 feet wide, and 10 feet deep. Each trench is filled with gravel to within 2 feet of the ground surface. Perforated pipe is laid on top of this gravel, and is covered by several more inches of gravel. The trench is then filled to the ground surface with original soil from the site. The perforated pipes that release effluent to the leaching field are at least 6 inches but no more than 2 feet below the ground surface, and are inclined at no more than 4 inches per 100 feet. The leaching field consists of several pipes in trenches at least 8 feet apart. HCHD requires that septic systems be located at least 15 feet from any property line, 75 to 100 feet from any ground water withdrawal wells, and 150 feet from wells that are below the grade of the septic system.

A septic system is also used for aquaculture effluent disposal at the Oneida Fish Hatchery in New York. Detailed information regarding the design of this leach field was not available for this report. For information regarding the basic operational practices at this facility, see Section 4.3.

Information about the design of the aquaculture waste disposal wells in Wyoming and California was not available for this report.

4.2.2 Siting Considerations

Hydrogeology is an important factor that influences both the likelihood that injectate from aquaculture waste disposal wells will affect USDWs, and the performance of injection wells themselves in disposing of wastewater. Permeable receiving formations comprise the most favorable injection formation for aquaculture effluent, due to the high solids content of the effluent. Low-permeability receiving formations can result in clogging and failure of aquaculture injection wells. However, these same factors that contribute to good well performance also increase the mobility of injectate within the receiving strata, and the likelihood that injectate will ultimately reach any nearby or underlying aquifer (if no impermeable barriers exist between the injection point and the aquifer).

Most of the injection wells in Hawaii, including aquaculture waste disposal wells, are located in the coastal region (seaward of the saltwater intrusion boundary) and release injectate directly into brackish or saline aquifers (Peterson and Oberdorfer, 1985). State officials believe that these wells pose no threat to USDWs, as the flow of the receiving saline aquifers is seaward, carrying injectate away from inland USDWs. The ground water table at these sites usually lies a few meters below the ground surface, and water table fluctuations resulting from ocean tides, storms, and seasonal changes in ground water recharge can significantly affect injection well performance (although USDWs remain unthreatened).

The aquaculture waste disposal well in Idaho is located in highly fractured basalt and discharges in such close proximity to the surface water discharge point that contaminants are adequately addressed through the NPDES permit requirements (Tallman, 1999).

The aquaculture waste disposal well (leaching field) in Maryland is situated above an aquifer classified as a “Type 1" aquifer, meaning that the quality of the water in the aquifer is excellent. The upper boundary of this aquifer is approximately 48 feet below the ground surface, or 38 feet below the bottom of the leaching trenches.[2]

Information regarding the hydrogeology at the aquaculture waste disposal wells in Wyoming, New York, and California was not available for this report.

4.3 Operational Practices

Available data indicate that operational practices could vary significantly among aquaculture waste disposal wells depending on various factors, including the hydrogeologic conditions at the well site, the state where the well is located, type of well, the nature of aquaculture activity, and the availability of other waste disposal options. This section describes operations at the systems for which information is available.

In Hawaii, aquaculture injection wells are used as a primary means of waste disposal, with a few wells used as standby wells or for backup drainage. Recorded pumping rates for individual wells range from 0.5 to 6 million gallons per day (gpd) (Pruder, 1992). Uehara (1999) reports that at the two Keahole Point facilities, effluent discharge rates of are 3,000 gpd and 5,760,000 gpd (for all wells combined), respectively. Wells at the Oceanic Institute are permitted an aggregate flow of 80,000 gpd, and those at Sea Life Park are permitted a flow of 18,008,000 gpd.

Unlike pressurized wastewater wells, aquaculture injection wells are usually gravity fed. The main operational concern is clogging due to poor site selection and a lack of maintenance. Clogging

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[2] State data indicate 39 drinking water wells within ½ mile of the operation. Fourteen of these wells range in depth from less than 100 feet to 150 feet, suggesting that they may tap the same shallow aquifer that underlies the aquaculture waste disposal system. The remaining wells range from 150 to over 350 feet deep, and may or may not tap this same aquifer.

can cause well overflow and possible ground water contamination from leaching of effluent that is discharged onto the ground. Pruder (1992) notes that clogging has occurred at several facilities in Hawaii. As experienced at the Kahuku Intensive Aquaculture Facility in Oahu, clogging of wells due to selection of a geologically unfavorable site with non- or poorly permeable soils can force an eventual abandonment of the wells. Aquaculture effluent at that location is now discharged into a ditch leading to an adjacent open, swampy wildlife refuge. Similar problems were encountered at wells owned by Marine Culture Enterprises at the same facility. In the first six months of operation there, one of the wells became irreversibly clogged and capacity at other wells was severely reduced despite all maintenance efforts. These injection wells are no longer in use.

In some other cases, improper handling and maintenance of the injection wells is found to cause clogging. For example, when the Ocean Farms Incorporated injection wells located at Keahole Point, Hawaii were first installed, settled materials were vacuumed from the bottom of the ponds and pressed down the wells, resulting in clogging. After the practice was stopped, the wells began to function properly (Pruder, 1992).

The deep injection well at Ten Springs Fish Farm, Idaho is not used as the primary means of wastewater disposal. The function of this injection well is to generate compressed air to aerate the fish pond, according to state officials and the operator (Anderson, 1999; Lemmon, 1999). Water from the fish pond goes to a settling pond for pre-treatment. Only a small portion of the wastewater is diverted from the settling pond to the well. The remainder of the effluent from the settling pond is discharged to a nearby stream. Wastewater sent to the injection well generates compressed air (the incoming water compresses the air already in the well), which is then returned to the fish pond through gravity force. This system functions on a continuous basis. The typical injection volume of the well is 450 gallons per minute (gpm); it has a capacity of 900 gpm.

The septic system in place at McGill Farms in Maryland is used for the disposal of wastes from biofilters and fish tanks. This tilapia farming facility consists of twelve 10,000 gallon fish culture tanks. Water from each of the tanks is re-circulated through a biofilter (also referred to as a “clarifier”). Material filtered from the recirculating water is treated further in the subsurface wastewater disposal system before being injected underground. The disposal system receives about 3,000 gpd from the twelve biofilters, one for each tank. Accumulated solid wastes, including fish fecal materials, are also discharged to the subsurface disposal system. In addition, approximately every two weeks (or during fish harvest), one of the twelve 10,000 gallon aquaculture tanks is drained. Water from the drained culture tanks is transferred to a holding tank, and gradually discharged into the subsurface disposal system.

Two 1,500-gallon septic tanks act as settling tanks for the McGill Farms subsurface disposal system; some (or possibly most) of the solids in the waste stream settle to the bottom of the tanks. Sludge is periodically pumped from the bottom of the septic tanks and is hauled away for disposal elsewhere. Only the supernatant from the septic tanks is injected to the underground leaching fields.

The Oneida Fish Hatchery in New York also uses a leaching field to dispose of aquaculture wastes. As described by Holeck et al. (1998), solids and wastewater from walleye rearing tanks are sent to two large (5,700 liter) above-ground concrete tanks for settling. After the particulates settle, the supernatant is removed and discharged underground via a leach field. The leach field has a maximum capacity of 13,250 liters per day. Not all of the wastes produced as a result of fish cultivation are discharged via subsurface injection -- the solids that accumulate in the settling tanks are applied to agricultural fields, while the hatchery "overtopping water" is discharged directly into a creek.

As with any underground disposal well, gravity-fed and pressurized aquaculture waste disposal wells are at risk to unauthorized discharges. Higher risks may be associated with gravity-fed wells if their wellheads are unsecured. However, most aquaculture injection wells are located within private facilities and are not accessible to the public for unsupervised waste disposal. The potential certainly exists for operators to dispose of harmful liquid wastes (e.g., waste aquaculture chemicals, or spent tank water with higher concentrations of chemicals used for temporary treatment of cultivated organisms) via aquaculture injection wells. However, no such cases have been reported and aquaculture wells generally are not vulnerable to spills or illicit discharges.

5. POTENTIAL AND DOCUMENTED DAMAGE TO USDWs

5.1 Injectate Constituent Properties

The primary constituent properties of concern when assessing the potential for Class V aquaculture waste disposal wells to adversely affect USDWs are toxicity, persistence, and mobility. The toxicity of a constituent is the potential of that contaminant to cause adverse health effects if consumed by humans. Appendix D of the Class V Study provides information on the health effects associated with contaminants found above drinking water MCLs or HALs in the injectate of aquaculture waste disposal wells and other Class V wells. As discussed in Section 4.1, the contaminants that have been observed above drinking water MCLs or HALs in aquaculture waste disposal well injectate are chloride, turbidity, and possibly nitrate and nitrite.

Persistence is the ability of a chemical to remain unchanged in composition, chemical state, and physical state over time. Appendix E of the Class V Study presents published half-lives of common constituents in fluids released in aquaculture waste disposal wells and other Class V wells. All of the values reported in Appendix E are for ground water. Caution is advised in interpreting these values because ambient conditions have a significant impact on the persistence of both inorganic and organic compounds. Appendix E also provides a discussion of mobility of certain constituents found in the injectate of aquaculture waste disposal wells and other Class V wells.

5.2 Observed Impacts

To date, no documented cases of impacts on USDWs or other ground water resources caused by aquaculture waste disposal wells have been observed.

6. BEST MANAGEMENT PRACTICES

Best management practices (BMPs) designed to minimize potential detrimental health and environmental effects that may result from injection of aquaculture wastes into wells are primarily focused on: reducing pollutant levels in effluent; reducing the volume of waste injected; or adopting alternative waste disposal options. The following discussion is neither exhaustive nor represents a USEPA preference for the stated BMPs. Each state or USEPA Region may require certain BMPs to be installed and maintained based on that state's or USEPA Region's priorities and site-specific considerations.

6.1 Reducing Pollutant Levels in Injectate

A variety of practices can be implemented to reduce pollutant levels in aquaculture effluent injectate. Goldburg and Triplett (1997), Mires (1995), and Boardman et al. (1998) suggest a number of "environmentally friendly" management practices for aquaculture wastes that can reduce pollutant levels and potential for harmful effects. Although these practices were suggested as methods to reduce pollutant levels in aquaculture effluent to surface water bodies, they are equally applicable for the reduction of pollutant concentrations in injectate at operations utilizing injection wells.

6.1.1 Improving Feeding Efficiency

Several key practices aimed at reducing the levels of pollutants in aquaculture effluents focus on reducing the amount of unconsumed feed, a primary source of nutrients and solids in these effluents. Such practices include:

- Optimization of the amount and type of feed applied in relation to the culture biomass, to reduce overfeeding;

- Accurate and frequent monitoring of fish growth and feeding rates, in order to determine the lowest amount of feed necessary to produce a given amount of fish biomass (i.e., maximization of the feed conversion ratio, or FCR); and

- Improvements in feed quality through the use of more digestible ingredients or reformulation to match fish needs. This can result in a higher FCR. However, one study found that high energy feed reduced total suspended solids but also increased total Kjeldahl nitrogen in the effluent due to greater nitrogen release from the fish receiving the high energy feed (Boardman et al., 1998).

6.1.2 Chemical Use Reduction

Although many types of biological compounds have become an integral part of modern intensive aquaculture (Mires, 1995), minimizing the use of chemicals, such as pesticides and pharmaceuticals, can reduce levels of potentially harmful substances in the effluent and lessen the potential for subsequent environmental impacts. For example, the application of pesticides in a calculated manner (e.g., certain amounts, types, time of year), rather than applying them liberally, would act to prevent over-usage and potentially needless contamination.

6.1.3 Technological Approaches

Certain technologies can also reduce pollutant levels in aquaculture effluents prior to disposal. Several are listed here:

- Sedimentation ponds allow suspended solids to settle out of the waste stream before disposal of the aqueous effluent. Nutrients and other pollutants are frequently adsorbed to the settled particulates. The University of Stirling (1990) has reported that up to 90 percent of suspended solids, 60 percent of biological oxygen demand, and 50 percent of total phosphorous loads can be removed through the use of these ponds. Sedimentation ponds can also reduce well clogging by removing solids.

- Retention ponds are similar to sedimentation ponds in that they allow solids to settle, but retention ponds hold the wastewater longer, allowing algae and nitrifying and denitrifying bacteria to transform, immobilize, and volatilize nitrogen. Phosphorus is mostly retained in the bottom sediments (Mires, 1995).

- Mechanical filtration and sediment traps can also reduce sediment and particulate levels in effluent. Several filtration systems exist, including low-head-swirl concentrators (rapidly rotating cylindrical chambers that remove suspended solids via centrifugal force), fine mesh filters, and sand and gravel filters (Goldburg and Triplett, 1997). Regular cleaning and maintenance of filtration systems will ensure efficient operation (Boardman et al., 1998).

- Biofilters utilize aerobic and anaerobic microbial filtration to remove organic matter and nutrients from aquaculture waters. Bivalve and macro-algae filter beds have also been used at marine aquaculture operations to accomplish the same results (Mires, 1995).

- Aeration and resuspension of solids can help to purify water by enhancing the aerobic decomposition of wastes. Resuspension of solids encourages bacteria to flocculate (form masses) around suspended particles; the bacteria can then be ingested or decomposed by fish in some cases (Mires, 1995).

However, technologies such as filtration systems and settling ponds generate large amounts of waste solids (i.e., sludge). Improper disposal of this sludge may introduce a separate set of health or safety problems (Boardman et al., 1998). Aquaculture facility operators generally do consider these factors when choosing an appropriate best management practice. However, by removing these solids from injectate, operators can reduce any impact of injectate on USDWs. Concentrated waste sludges are of considerably less volume than the original effluent, making them easier to manage by means other than underground injection.

In addition, the nutrient-rich sludge removed from effluent waters by the settling and filtration processes discussed here can be used as a soil amending agent (e.g., compost) and/or can be applied to agricultural crops as a fertilizer. It may also prove useful for some types of integrated farming. Integrated farming -- combining terrestrial agriculture and aquaculture -- includes various types of practices, including polyculture (i.e., the cultivation of more than one species of plant or animal in a single place or system) and hydroponics (i.e., the cultivation of plants rooted in an aqueous nutrient solution rather than in soil) (McLarney, 1984).

6.2 Reducing Injectate Volume

The rate of water use and disposal by aquaculture operations can be greatly reduced through the use of water recirculating systems, as opposed to flow-through systems (Goldburg and Triplett, 1997). Recirculating systems allow water to be circulated through culture tanks several times. This greatly reduces the demand for fresh intake water and the rate of wastewater production, and makes them more desirable financially. Recirculated water is generally filtered and aerated in order to maintain a suitable level of cleanliness and oxygenation. The filtration process results in the generation of concentrated sludge wastes that require management and disposal, as noted above.

6.3 Closure; Use of Alternative Disposal Methods

In a study of Hawaiian aquaculture, Pruder (1992) considered several options for aquaculture waste disposal in an effort to find an alternative to coastal water discharge and eliminate NPDES/ZOM (Zones of Mixing) permit requirements. Several of the disposal options considered by Pruder (1992) could also be considered as alternatives to waste injection wells, or could be used in conjunction with injection wells to decrease the amount of waste requiring underground injection. Options (other than well injection) considered by Pruder included: deep ocean outfall pipes, recycling systems, polyculture, solids removal, trenches, and leaky ponds (earthen ponds that slowly leak effluent into the ground). All of these represent potential alternatives to injection of wastes into Class V wells for the disposal or aquaculture wastes. Although trenches and leaky ponds might provide more filtration as the wastewater migrates through the unsaturated zone, it is questionable if such disposal would be preferable to underground injection from the standpoint of aquifer protection. The cost and feasibility of these alternatives would have to be examined on a case-specific basis to determine whether a particular alternative is desirable.

7. CURRENT REGULATORY REQUIREMENTS

Several federal, state, and local programs exist that either directly manage or regulate Class V aquaculture waste disposal wells. On the federal level, management and regulation of these wells falls primarily under the UIC program authorized by the Safe Drinking Water Act (SDWA). Some states and localities have used these authorities, as well as their own authorities, to extend the controls in their areas to address concerns associated with aquaculture waste disposal wells.

7.1 Federal Programs

Class V wells are regulated under the authority of Part C of SDWA. Congress enacted the SDWA to ensure protection of the quality of drinking water in the United States, and Part C specifically mandates the regulation of underground injection of fluids through wells. USEPA has promulgated a series of UIC regulations under this authority. USEPA directly implements these regulations for Class V wells in 19 states or territories (Alaska, American Samoa, Arizona, California, Colorado, Hawaii, Indiana, Iowa, Kentucky, Michigan, Minnesota, Montana, New York, Pennsylvania, South Dakota, Tennessee, Virginia, Virgin Islands, and Washington, DC). USEPA also directly implements all Class V UIC programs on Tribal lands. In all other states, which are called Primacy States, state agencies implement the Class V UIC program, with primary enforcement responsibility.

Aquaculture waste disposal wells currently are not subject to any specific regulations tailored just for them, but rather are subject to the UIC regulations that exist for all Class V wells. Under 40 CFR 144.12(a), owners or operators of all injection wells, including aquaculture waste disposal wells, are prohibited from engaging in any injection activity that allows the movement of fluids containing any contaminant into USDWs, "if the presence of that contaminant may cause a violation of any primary drinking water regulation . . . or may otherwise adversely affect the health of persons."

Owners or operators of Class V wells are required to submit basic inventory information under 40 CFR 144.26. When the owner or operator submits inventory information and is operating the well such that a USDW is not endangered, the operation of the Class V well is authorized by rule. Moreover, under section 144.27, USEPA may require owners or operators of any Class V well, in USEPA-administered programs, to submit additional information deemed necessary to protect USDWs. Owners or operators who fail to submit the information required under sections 144.26 and 144.27 are prohibited from using their wells.

Sections 144.12(c) and (d) prescribe mandatory and discretionary actions to be taken by the UIC Program Director if a Class V well is not in compliance with section 144.12(a). Specifically, the Director must choose between requiring the injector to apply for an individual permit, ordering such action as closure of the well to prevent endangerment, or taking an enforcement action. Because aquaculture waste disposal wells (like other kinds of Class V wells) are authorized by rule, they do not have to obtain a permit unless required to do so by the UIC Program Director under 40 CFR 144.25. Authorization by rule terminates upon the effective date of a permit issued or upon proper closure of the well.

Separate from the UIC program, the SDWA Amendments of 1996 establish a requirement for source water assessments. USEPA published guidance describing how the states should carry out a source water assessment program within the state's boundaries. The final guidance, entitled *Source Water Assessment and Programs Guidance* (USEPA 816-R-97-009), was released in August 1997.

State staff must conduct source water assessments that are comprised of three steps. First, state staff must delineate the boundaries of the assessment areas in the state from which one or more public drinking water systems receive supplies of drinking water. In delineating these areas, state staff must use “all reasonably available hydrogeologic information on the sources of the supply of drinking water in the state and the water flow, recharge, and discharge and any other reliable information as the state deems necessary to adequately determine such areas.” Second, the state staff must identify contaminants of concern, and for those contaminants, they must inventory significant potential sources of contamination in delineated source water protection areas. Class V wells, including aquaculture waste disposal wells, should be considered as part of this source inventory, if present in a given area. Third, the state staff must “determine the susceptibility of the public water systems in the delineated area to such contaminants.” State staff should complete all of these steps by May 2003 according to the final guidance.[3]

7.2 State and Local Programs

As discussed in Section 3 above, a total of 56 Class V aquaculture waste disposal wells are documented to occur across the nation. Hawaii, Idaho, Maryland, New York, and Wyoming have documented aquaculture waste disposal wells, and wells are thought to exist in California. Attachment B of this volume describes how aquaculture waste disposal wells are addressed in each of these states. In brief:

USEPA directly implements the UIC Class V program in California, Hawaii, and New York. In addition, California and New York also have state programs to protect ground water that can address aquaculture waste disposal wells.

- In California, USEPA Region 9 directly implements the Class V UIC program. In addition, under the California Water Quality Control Act, nine Regional Water Quality Control Boards coordinate and advance water quality in each region. These Boards may prescribe discharge requirements for discharges into the waters of the state under regional water quality control plans.

- In Hawaii, USEPA Region 9 directly implements the Class V UIC program. In addition, aquaculture waste disposal wells are authorized by individual permits issued by the state Department of Health. Class V wells are subject to siting requirements, and prohibited from operating in a manner that allows the movement of contaminants into a USDW.

- In New York, the Class V UIC program is directly implemented by USEPA Region 2. The state also implements a State Pollution Discharge Elimination System (SPDES) to protect the waters of the state, which include ground waters. Aquaculture waste disposal wells can be required to obtain an SPDES permit for discharges into ground water. Permit conditions can

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[3] May 2003 is the deadline including an 18-month extension.

include construction and operation requirements for septic systems used to dispose of industrial waste.

In the three states that are Primacy States for the UIC Class V program, Idaho, Maryland, and Wyoming, aquaculture waste disposal wells are either individually permitted or covered by a general permit that includes conditions similar to those of an individual permit.

- In Idaho, wells greater than 18 feet deep are individually permitted, while shallower wells are authorized by rule. The state has enacted an antidegradation policy to maintain the existing uses of all ground water.

- In Maryland, in addition to the state's UIC Class V program, the state's pollution discharge elimination system can require permits for discharges into ground water. Individual permits are required for any discharge of pollutants to ground water, for any industrial discharge of wastewater to a well or septic system, for any septic system with 5,000 gpd or greater capacity, or for any well that injects fluid directly into a USDW. County health departments, as well as the state Department of the Environment, can oversee aquaculture waste discharge wells.

- In Wyoming, aquaculture wells are covered under a general permit under the state's Class V UIC program. The permit covers a class of operators, all of whom inject similar types of fluids for similar purposes, and requires somewhat less information to be submitted by the applicant than is required by an individual permit. The well must satisfy specific construction and operating requirements (e.g., pretreatment of wastewater).

ATTACHMENT A
DRUGS, CHEMICALS, AND BIOTICS USED IN AQUACULTURE

Table A1. FDA-Approved Drugs Used in Aquaculture

Trade name	Active Drug	Species and Uses
Finquel (MS-222)	Tricaine methanesul-fonate	Temporary immobilization (anesthetic) for Ictaluridae, Salmonidae, Esocidae, and Percidae. For approved uses for other poikilothermic animals, refer to the product label.
Formalin-F	Formalin	Control of external protozoa and monogenetic trematodes in trout, salmon, catfish, large-mouth bass, and bluegill. Control of fungi of the family Saprolegniacae on salmon, trout, and esocid eggs.
Paracide-F	Formalin	Control of external protozoa, monogenetic trematodes, and fungi in trout, salmon, catfish, large-mouth bass, and bluegill. Control of fungi of the family Saprolegniacae on salmon, trout, and esocid eggs.
Parasite-S	Formalin	Control of external protozoa and monogenetic trematodes in all fish. Control of fungi of the family Saprolegniacae on all fish eggs. Control of external protozoan parasites on cultured penaeid shrimp.
Romet 30	Sulfadimethoxine and ormetoprim	Control of enteric septicemia in catfish. Control of furunculosis in salmonids.
Sulfamerazine in Fish Grade	Sulfamerizine	Control of furunculosis in rainbow trout, brook trout, and brown trout. [1]
Terramycin For Fish	Oxytetracycline	Control of bacterial hemorrhagic septicemia and control of gaffkemia in lobsters. Control of ulcer disease, furunculosis, bacterial hemorrhagic septicemia, pseudomonas disease in salmonids. Marking of skeletal tissue in Pacific salmon.

Source: Texas Agricultural Extension Service, 1994.

Table A2. Drugs of Low Regulatory Priority for FDA Used in Aquaculture

Name	Uses
Acetic acid	Used as a dip at a concentration of 1,000-2,000 milligrams per liter (mg/l) for 1-10 minutes as a parasiticide for fish.
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 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.
Calcium oxide	Used as an external protozoacide for fingerling to adult fish at a concentration of 2,000 mg/l for 5 seconds.
Carbon dioxide gas	Used for anesthetic purposes in cold, cool, and warm water fish.
Fuller's earth	Used to reduce the adhesiveness of fish eggs in order to improve hatchability.
Garlic (whole)	Used for control of helminth and sea lice infestations in marine salmonids at all life stages.
Hydrogen Peroxide	Used at 250-500 mg/l to control fungi on all species and at all life stages of fish, including eggs.
Ice	Used to reduce metabolic rate of fish during transport.
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 30,000 mg/l magnesium sulfate and 7,000 mg/l sodium chloride for 5-10 minutes.
Onion (whole)	Permitted use: Used to treat external crustacean parasites and to deter sea lice from infesting external surface of fish at all life stages.
Papain	Used as a 0.2% solution in removing the gelatinous matrix of fish egg masses in order to improve hatchability and decrease the incidence of disease.
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.
Povidone iodine compounds	Used as a fish egg disinfectant at rates of 50 mg/l for 30 minutes during water hardening and 100 mg/l solution for 10 minutes after water hardening.
Sodium bicarbonate (baking soda)	Used at 142-642 mg/l for 5 minutes as a means of introducing carbon dioxide into the water to anesthetize fish.
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 minutes as a parasiticide.
Sodium sulfite	Used as a 15% solution for 5-8 minutes to treat eggs in order to improve hatchability.
Urea and tannic acid	Used to denature the adhesive component of fish eggs at concentrations of 15 g urea and 20 NaCl/5 l of water for approximately 6 minutes, followed by a separate solution of 0.75 g tannic acid/5 l water for an additional 6 minutes. These amounts will treat approximately 400,000 eggs.

Source: Texas Agricultural Extension Service, 1994.

Table A3. USEPA-Registered Algaecides for Aquaculture/Aquatic Sites

Trade Name	USEPA Reg. No.	Registrant	Indications For Use
Common name: Chelated Copper			
Algae-Rhap CU-7 Liquid	55146-42	Agtrol Chemical Products	Broad-range algaecide for use in farm and fish ponds, lakes, and fish hatcheries.
Algimycin PLL	7364-10	Great Lakes Biochemical Co., Inc.	Algaecide for small, ornamental ponds and pools.
Algimycin PLL-C	7364-9	Great Lakes Biochemical Co., Inc.	Algaecide for pools, lakes, ponds, and similar waters.
Aquatrine Algaecide	8959-33	Applied Biochemists, Inc.	Algaecide for fish and shrimp aquaculture facilities (e.g., ponds, tanks, and raceways).[4]
Copper Control Granular	47677-8	Argent Chemical Laboratories, Inc	Algaecide for fish ponds and hatcheries.
Cutrine Algaecide	8959-1	Applied Biochemists, Inc.	Algaecide for fish ponds, lakes, and hatcheries.[5]
Cutrine Granular Algaecide	8959-3	Applied Biochemists, Inc.	Granular algaecide for control of Chara and Nitella in fish ponds, lakes, and hatcheries. [5]
Cutrine Plus Algaecide /Herbicide	8959-10	Applied Biochemists, Inc	Algaecide/herbicide for fish ponds, lakes, and hatcheries.
Cutrine Plus II Algaecide	8959-20	Applied Biochemists, Inc.	Algaecide for fish ponds, lakes, and hatcheries.[5]
Cutrine Plus Granular Algaecide	8959-12	Applied Biochemists, Inc.	Algaecide (especially for Chara and Nitella) in fish ponds and hatcheries.
Cutrine Plus granular Algaecide	8959-12	Applied Biochemists, Inc	Algaecide (especially for Chara and Nitella) in fish ponds and hatcheries.
Komeen Aquatic Herbicide	1812-312	Griffin Corporation	Algaecide for freshwater lakes and fish hatcheries.
K-Tea Algaecide	1812-307	Griffin Corporation	Algaecide for freshwater lakes and fish hatcheries.
SCI-62 Algaecide/ Bactericide	61943-1	Chem-A-Co., Inc.	Algaecide/bactericide for lakes and ponds.
Slow Release Algimycin PLL Concentrate	7364-26	Great Lakes Biochemical Co., Inc.	Algaecide (especially for Chara and Nitella) in ponds and lakes.
Common name: Copper			
Alco Cutrine Algaecide RTU	5481-140	Amvac Chemical Corporation	Algaecide for fish ponds, lakes, and hatcheries.[5]

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[4] Note: According to registrant, this product is not presently being distributed.

Table A3. USEPA-Registered Algaecides for Aquaculture/Aquatic Sites (cont'd)

Trade Name	USEPA Reg. No.	Registrant	Indications For Use
Common name: Copper as elemental			
Algon Algaecide	11474-15	Sungro Chemicals, Inc.	Algaecide for use in lakes, fish ponds, and fish hatcheries.
AV-70 Plus Algaecides	12014-10	A & V Inc.	Algaecides for fish ponds, lakes, and hatcheries.
A & V-70 Granular Algaecide	12014-5	A & V Inc.	Granular algaecide for lakes and ponds.[5]
Common name: Copper sulfate pentahydrate			
Blue Viking Kocide Copper Sulfate Star Glow Powder	1812-314	Griffin Corporation	Algaecide for freshwater lakes and ponds.
Blue Viking Kocide Copper Sulfate Star Shine Crystals	1812-313	Griffin Corporation	Algaecide for lakes, ponds, and impounded water.
Calco Copper Sulfate	39295-8	Calabrian International Corporation	For algae control in impounded water, lakes, and ponds.[6]
Copper Sulfate Crystals	56576-1	Chem One Corporation	Algae control in impounded lakes and ponds.
Copper sulfate Large Crystal	1109-1	Boliden Intertrade, Inc	For algae control in lakes and ponds.
Copper Sulfate Medium Crystals	1109-19	Boliden Intertrade, Inc.	For algae control in lakes and ponds.
Copper Sulfate Pentahydrate Algaecide/Herbicide	35896-19	C.P. Chemicals	Algaecide/herbicide for controlled-outflow lakes and ponds.
Copper Sulfate Superfine Crystals	1109-32	Boliden Intertrade, Inc.	For algae control in lakes and ponds.
Copper Sulfate Powder	1109-7	Boliden Intertrade, Inc	For algae control in lakes and ponds.
Dionne Root Eliminator	34797-39	Qualis, Inc.	For algae control in lakes and ponds.
Granular Crystals Copper Sulfate	1109-20	Boliden Intertrade, Inc.	For algae control in lakes and ponds.
Kocide Copper Sulfate Pentahydrate Crystals	1812-304	Griffin Corporation	Algaecide for lakes and ponds.[6]
Root Killer RK-11	8123-117	Frank Miller & Sons, Inc.	For algae control in impounded waters (e.g., lakes, ponds).[6]
SA-50 Brand Copper Sulfate Granular Crystals	829-210	Southern Agricultural Insecticides, Inc.	For algae control in ponds.
Snow Crystals Copper Sulfate	1109-21	Boliden Intertrade, Inc.	For algae control in lakes and ponds.
Triangle Brand Copper Sulfate Crystals	1278-8	Phelps Dodge Refining Corporation	For algae control in impounded waters, lakes, ponds, and reservoirs.

Source: Texas Agricultural Extension Service, 1994.

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[5] Note: According to registrant, this product is not presently being distributed.

Table A4. USEPA-Registered Fish Toxicants

Trade Name	USEPA Registration Number	Registrant	Comments and Indications For Use
Common name: Antimycin			
Fintrol Concentrate	39096-2	Aquabiotics Corporation	Fish toxicant/ piscicide
Common name: Cube Resins/Rotenone			
Chem-Sect Brand Chem Fish Regular	1439-157	Tifa Limited Cube resins/rotenone	Fish toxicant/ piscicide
Chem-Fish Synergized	1439-159	Tifa Limited	Fish toxicant/ piscicide
Finely Ground Cube Powder	6458-6	Foreign Domestic Chemicals Corp	Fish toxicant/ piscicide
Fish-Tox-5	769-309	Sureco, Inc.	Fish toxicant/ piscicide
Martin's Rotenone Powder	299-227	C.J. Martin Company	Fish toxicant/ piscicide
Noxfish Fish Toxicant Liquid Emulsifiable	432-172	Roussel Uclaf Corporation	Fish toxicant/ piscicide
Nusyn-Noxfish Fish Toxicant	432-550	Roussel Uclaf Corporation	Fish toxicant/ piscicide
Pearson's 5% Rotenone Wettable Powder	19713-316	Drexel Chemical Company	Fish toxicant/ piscicide
Powdered Cube	769-414	Sureco, Inc.	Fish toxicant/ piscicide
Prentox Prenfish Toxicant	655-422	Prentiss Incorporated	Fish toxicant/ piscicide
Prentox Rotenone Fish Toxicant Powder	655-691	Prentiss Incorporated	Fish toxicant/ piscicide
Prentox Synpren Fish Toxicant	655-421	Prentiss Incorporated	Fish toxicant/ piscicide
Rotenone 5% Liquid Emulsifiable	47677-3	Argent Chemical Laboratories, Inc.	Fish toxicant/ piscicide
Rotenone 5% Fish Toxicant Powder	47677-4	Argent Chemical Laboratories, Inc.	Fish toxicant/ piscicide

Note: Restricted use products such as rotenone fish toxicants can be purchased only by a Certified Pesticide Applicator and can be applied only by a Certified Pesticide Applicator or under a certified applicator's direct supervision.

Source: Texas Agricultural Extension Service, 1994.

Table A5. USEPA-Registered Herbicides

Trade Name	USEPA Registration Number	Registrant	Comments and Indications For Use
Common name: Acid blue and acid yellow			
Aquashade	33068-1	Applied Biochemists, Inc.	Aquatic plant control through selective light filtering; usable in controlled-outflow natural and man- made lakes and ponds.
Common name: Dichlobenil			
Acme Norosac 10G	2217-679	PBI/Gordon Corporation	Aquatic weed control for lakes and ponds.
Casoron 10-G	400-178	Uniroyal Chemical Company, Inc.	Aquatic herbicide for submerged weeds in non-flowing water.
Common name: Diquat dibromide			
Aqua Clear	2155-63	I. Schneid, Inc.	Contact, non-selective vegetation killer for aquatic weeds.
Aqua-Kil Plus	37347-6	Uni-Chem Corporation of Florida	Contact, non-selective vegetation killer to control aquatic weeds and grasses.
Aquaquat	5080-4	Aquacide Company	Liquid weed killer for lakes and ponds with controlled outflow.
Aquatic Weed Killer	10292-13	Venus Laboratories, Inc.	For the elimination of aquatic weeds and algae.[6]
Clean-Up	2155-64	I. Schneid, Inc.	Algaecide and non-selective weed killer.
Conkill	10088-13	Athea Laboratories, Inc.	Contact, non-selective herbicide for aquatic weeds.
Contact Vegetation Controller	8123-102	Frank Miller & Sons, Inc	For the control of aquatic vegetation.
Diquat-L Weed Killer 1/5 Lb.	34704-589	Platte Chemical Co., Inc.	Aquatic weed killer for controlled-outflow lakes and ponds.
Formula 268 AquaQuat	1685-64	State Chemical Manufacturing Company	Aquatic weed killer in lakes, ponds, and impounded water.
Ind-Sol 435	10827-78	Chemical Specialties, Inc.	Non-selective weed killer for controlled -outflow lakes and ponds.
Miller Liquid Vegetation Control	8123-37	Frank Miller & Sons, Inc	For the control of aquatic vegetation.
No. 401 Water Plant Killer	11515-29	ABC Chemical Corporation	Contact, non-selective weed killer for aquatic weeds.
Norkem 500	5197-37	Systems General, Inc.	Contact, non-selective weed killer for controlled-outflow ponds and lakes.

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[6] Note: According to registrant, this product is not presently being distributed.

Table A5. USEPA-Registered Herbicides (cont'd)

Trade Name	USEPA Registration Number	Registrant	Comments and Indications For Use
P.D.Q. Non-Selective Weed Killer	2155-43	I. Schneid, Inc.	Algaecide and non-selective weed killer.
Selig's Mister Trim No. 10	491-201	Selig Chemical Industries	Contact, non-selective killer for aquatic weeds.
Watrol	1769-174	NCH Corporation	Herbicide for aquatic weeds.
Weedtrine D Aquatic Herbicide	8959-9	Applied Biochemists, Inc.	Aquatic herbicide for still lakes and fish ponds.
Yardman	10663-11	Sentry Chemical Company	Nons-elective weed, algae, and aquatic foliage killer.
Common name: Endothall			
Aquathol Granular Aquatic Herbicide	4581-201	Elf Atochem North America, Inc.	Aquatic herbicide in ponds and lakes.
Aquathol K Aquatic Herbicide	4581-204	Elf Atochem North America, Inc.	Contact aquatic herbicide for lakes and ponds.
Hydrothol 191 Aquatic Algaecide and Herbicide	4581-174	Elf Atochem North America, Inc.	Aquatic algaecide/ herbicide for lakes and ponds.
Hydrothol 191 Granular Aquatic Algaecide and Herbicide	4581-172	Elf Atohem North America, Inc.	Aquatic algaecide/ herbicide for lakes and ponds.
Common name: Fluridone			
Sonar A.S.	62719-124	DowElanco	Herbicide for the management of aquatic vegetation in freshwater ponds, lakes, and drainage canals.
Sonar SRP	62719-123	DowElanco	Herbicide for the management of aquatic vegetation in freshwater ponds, lakes, and drainage canals.
Common name: Glyphosate			
Rodeo	524-343	The Agricultural Group of Monsanto Company	Aquatic herbicide for freshwater and brackish water applications.
Common name: 2,4-D			
Weed-Rhap A-4D	5905-501	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.
Weed-Rhap A-6D Herbicide	5905-503	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.
Common name: Acetic Acid, 2,4			
A C Aquacide Pellets	5080-2	Aquacide Company	Herbicide for submerged weeds in recreational lakes and ponds. Predominantly for broad-leafed plants.

Table A5. USEPA-Registered Herbicides (cont'd)

Trade Name	USEPA Registration Number	Registrant	Comments and Indications For Use
Common name: 2,4-D and Butoxyethyl Ester			
Aqua-Kleen	264-109	Rhone-Poulenc Agricultural Co.	Granular aquatic herbicide for controlling weeds.
Navigate	264-109-8959	Applied Biochemists, Inc.	For control of aquatic weeds in lakes and ponds.
Common name: Dimethylamine salt of 2,4-D			
Clean Crop Amine 2,4-D Granulese:	34704-645	Platte Chemical Co., Inc	Aquatic herbicide for immersed/ submerged weeds.[7]
Clean Crop Amine 6 2,4-D Herbicide	34704-646	Platte Chemical Co., Inc.	Herbicide for lakes and ponds.
Rhodia 2,4-D Gran 20	42750-16	Albaugh	Herbicide for aquatic weeds in lakes and ponds.[8]
Weedestroy AM-40 Amine Salt	228-145	Riverdale Chemical Company	For control of broadleaf weeds and aquatic weeds in lakes and ponds.
2,4-D Amine 4 Herbicide	42750-19	Albaugh	Herbicide for aquatic weeds in lakes and ponds.
2,4-D Amine 6 Herbicide	42750-21	Albaugh	Herbicide for aquatic weeds in lakes and ponds.
2,4-D380 Amine Weed Killer	407-430	Imperial, Inc.	Aquatic herbicide for lakes and ponds.
Weedar 64	264-2	Rhone-Poulenc Agricultural Co.	Broadleaf herbicide; toxic to aquatic invertebrates.

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[7] Note: According to registrant, this product is not presently being distributed.

Table A5. USEPA-Registered Herbicides (cont'd)

Trade Name	USEPA Registration Number	Registrant	Comments and Indications For Use
Common name: Isooctyl ester of 2,4-D			
Barrage (Weed-Rhap LV-5D Herbicide)	5905-504	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.
Brush-Rhap Low Volatile 4-D Herbicide	5905-498	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.
2,4-D Granules	228-61	Riverdale Chemical Company	For control of broadleaf and certain aquatic weeds.
2,4-D L. V. 4 Ester	228-139	Riverdale Chemical Company	For control of aquatic weeds in lakes and ponds.
2,4-D L. V. 6 Ester	228-95	Riverdale Chemical Company	For control of aquatic weeds in lakes and ponds.
SEE 2,4-D Low Volatile Ester Solventless Herbicide	42750-22	Albaugh	Herbicide for aquatic weeds in lakes and ponds.
2,4-D L. V. 4 Ester	228-139	Riverdale Chemical Company	For control of aquatic weeds in lakes and ponds.[8]
2,4-D LV Ester 6	5905-93	Helena Chemical Company	Selective aquatic herbicide.[9]
Visko-Rhap Low Volatile Ester 2D	42750-17	Albaugh	Herbicide for aquatic weeds in lakes and ponds.[9]
Weed-Rhap Low Volatile Granular D Herbicide	5905-507	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.
Weed-Rhap LV-4D Herbicide	5905-505	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.
Weed-Rhap LV-6D	5905-508	Helena Chemical Company	For control of aquatic weeds in lakes and ponds.[9]

Source: Texas Agricultural Extension Service, 1994.

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[8] Note: According to registrant, this product is not presently being distributed.

Table A6. USDA-Licensed Biologics for Fish (Vaccines)

Product Name/Trade Name	Licenses/ Permittee	Species	Disease
Aeromonas Salmonicida Bacterin Biojec 1500	BioMed, Inc	Salmonids	Furunculosis
Aeromonas Salmonicida-Vibrio	BioMed, Inc.	Salmonids	Furunculosis, vibriosis
Autogenous Bacterin Autogenous Bacterin	BioMed, Inc	Fish	Bacterial diseases
Vibrio Anguillarum-Ordalii Bacterin	BioMed, Inc.	Salmonids	Vibriosis
Vibrio Anguillarum-Ordalii-Yersinia Ruckeri Bacterin	BioMed, Inc.	Salmonids	Vibriosis, yersiniosis (enteric red- mouth disease)
Yersinia Ruckeri Bacterin	Biomed, Inc	Salmonids	Yersiniosis (enteric red-mouth disease)
Vibrio Salmonicida Bacterin	BioMed, Inc.	Salmonids	Vibriosis
Vibrio Anguillarum-Salmonicida Bacterin	BioMed, Inc.	Salmonids	Vibriosis
Aeromonas Salmonicida Bacterin	Jerry Zinn, Aqua Health, Ltd.	Salmonids	Furunculosis
Autogenous Bacterin	Jerry Zinn, Aqua Health, Ltd.	Fish	Bacterial diseases
Edwardsiella Ictaluri Bacterin	Jerry Zinn, Aqua Health, Ltd.	Catfish	Enteric septicemia
Vibrio Anguillarum-Ordalii Bacterin	Jerry Zinn, Aqua Health, Ltd.	Salmonids	Vibriosis
Vibrio Anguillarum-Ordalii Bacterin	Jerry Zinn, Aqua Health, Ltd.	Salmonids	Vibriosis
Yersinia Ruckeri Bacterin	Jerry Zinn, Aqua Health, Ltd.	Salmonids	Yersiniosis (enteric red-mouth disease)

Source: Texas Agricultural Extension Service, 1994.

ATTACHMENT B
STATE AND LOCAL PROGRAM DESCRIPTIONS

In this attachment, summary information for state and local regulations and guidance pertaining to aquaculture waste disposal wells is provided below for the six states known or believed to have such wells.

California

USEPA Region 9 directly implements the Class V UIC program in California and the federal UIC regulations apply to Class V wells in this state.

In addition, the California Water Quality Control Act (WQCA) establishes broad requirements for the coordination and control of water quality in the State, sets up a State Water Quality Control Board, and divides the State into nine regions, each with a Regional Water Quality Control Board (RWQCB) that is delegated responsibilities and authorities to coordinate and advance the water quality of the region (Chapter 4 Article 2 WQCA). A RWQCB can prescribe requirements for discharges into the waters of the State (13263 WQCA), and these waste discharge requirements can apply to injection wells (13263.5 and 13264(b)(3) WQCA). Although the RWQCBs do not issue permits for injection wells, the WQCA provides that any person operating, or proposing to operate, an injection well (as defined in §13051 WQCA) must file a report of the discharge with the appropriate RWQCB (13260(a)(3) WQCA). Furthermore, the RWQCB, after any necessary hearing, may prescribe requirements concerning the nature of any proposed discharge, existing discharge, or material change in an existing discharge to implement any relevant regional water quality control plans. However, a RWQCB may waive the requirements in 13260(a) and 13253(a) for a specific discharge or a specific type of discharge when the waiver is not against the public interest (13269(a) WQCA). No RWQCB is known to have established discharge limits for aquaculture waste wells in the state.

Hawaii

USEPA Region 9 directly implements the Class V UIC program in Hawaii. In addition, the Safe Drinking Water Branch within the Hawaii Department of Health administers a Class V UIC Program. Chapter 23 of Title 11 of the Hawaii Administrative Rules (HAR), effective July 6, 1984, amended November 12, 1992, established this program.

Class V wells are grouped for purposes of permitting into 6 subclasses. Subclass B includes wells that inject non-polluting fluids into any geohydrologic formation, including USDWs. Subclass B(E) consists of wells used in aquaculture, if the water in the receiving formation has either (a) an equal or greater chloride concentration as that of the injected fluid, or (b) a TDS concentration in excess of 5,000 mg/l (11-23-06(b)(3) HAR).

Permitting

Underground injection through a Class V well is prohibited except as authorized by permit. A permit for injection into USDWs will be based on evaluation of the contamination potential of the local water quality by the injection fluids and the water development potential for public or private consumption. Permits are issued not to exceed five years. Permit applications must include specified information (11-23-12, 11-23-13, and 11-23-16 HAR).

Siting and Construction

Wells are required to be sited beyond an area that extends at least one-quarter mile from any part of a drinking water source, including not only the surface expression of the water supply well, tunnel, or spring, but also all portions of the subsurface collection system (the so-called "UIC line"). Special buffer zones are required if the well is located in a caprock formation that overlies a volcanic USDW under artesian pressure (11-23-10 HAR).

No injection well may be constructed unless a permit application has been made and the construction has been approved. Specific construction standards for each type of well are not specified, due to the variety of injection wells and their uses. If large voids such as lava tubes or solution cavities are encountered, special measures must be taken to prevent unacceptable migration of the injected fluids (11-23-09 HAR).

Operating Requirements

A Class V well may not be operated in a manner that allows the movement of fluid containing a contaminant into a USDW, if the presence of that contaminant may cause a violation of any national or state primary drinking water rule or otherwise adversely affect the health of one or more persons. All wells must be operated in such a manner that they do not violate any rules under Title 11 HAR regulating water quality and pollution, including Chapter 11-20 (potable water systems), Chapter 11-62 (wastewater systems), and Chapter 11-55 (water pollution control). State staff may also impose other limitations on the quantity and quality of injectate as deemed appropriate. An operator may be ordered to take such actions as may be necessary, including cessation of operations, to prevent a violation of primary drinking water standards (11-23-11 HAR). The rules pertaining to wastewater systems (Title 11 Chapter 62 HAR) specify wastewater effluent requirements applicable to treatment works (11-62-26 HAR) for BOD and suspended solids, adopt by reference USEPA regulations in 40 CFR 125 and 40 CFR 133, and specify a chlorine residual for treatment works using a subsurface disposal system other than soil absorption. They also specify peak flow and backup requirements for proposed subsurface disposal systems (11-62-25 HAR).

Monitoring Requirements

Operating records will be required for aquaculture wells, including the type and quantity of injected fluids and the method and rate of injection (11-23-12 HAR). In addition to the detection of potential environmental impacts, frequent well monitoring also acts to minimize chances for well malfunction. To date, well failure has not been documented (Wong, 1999).

Plugging and Abandonment

An operator wishing to abandon a well must submit an application, and the well must be plugged in a manner that will not allow detrimental movement of fluids between formations (11-23-19 HAR).

Idaho

Idaho is a Primacy State with respect to the Class V UIC program, and has promulgated regulations covering all Class V wells. In addition the state's Ground Water Quality Protection Act establishes an antidegradation policy.

Permitting

Under Idaho regulations, deep injection wells ($ 18 feet below the land surface) require permits. Shallow injection wells are authorized by rule, provided that wells do not threaten any USDW, the injectate meets drinking water standards, and their operators provide inventory information to state authorities. The regulations outline detailed specifications for the information that must be supplied in a permit application (37.03.03.035 IDAPA). At least one injection well in the state receives aquaculture effluent, and it is permitted as a deep injection well.

Operating Requirements

Standards for the quality of injected fluids and criteria for location and use are established for rule-authorized wells, as well as for wells requiring permits. The rules are based on the premise that if the injected fluids meet MCLs for drinking water for physical, chemical, and radiological contaminants at the wellhead, and if ground water produced from adjacent points of diversion for beneficial use meets the water quality standards found in Idaho's "Water Quality Standards and Wastewater Treatment Requirements," 16.01.02 IDAPA, administered by the Idaho Department of Health and Welfare, the aquifer will be protected from unreasonable contamination. The State of Idaho may, when it is deemed necessary, require specific injection wells to be constructed and operated in compliance with additional requirements (37.03.03.050. 01 IDAPA (Rule 50)). Rule-authorized wells "shall conform to the drinking water standards at the point of injection and not cause any water quality standards to be violated at the point of beneficial use" (37.03.03.050.04.d IDAPA).

Monitoring, record keeping, and reporting may be required if state officials find that the well may adversely affect a drinking water source or is injecting a contaminant that could have an unacceptable effect upon the quality of the ground waters of the state (37.03.03.055 IDAPA (Rule 55)).

Plugging and Abandonment

The Idaho Department of Water Resources (IDWR) has prepared "General Guidelines for Abandonment of Injection Wells," which are not included in the regulatory requirements. IDWR expects to approve the final abandonment procedure for each well. The General Guidelines recommend the following:

- Pull casing, if possible. If casing is not pulled, cut casing a minimum of two feet below land surface.

- The total depth of the well should be measured.

- If the casing is left in place, it should be perforated and neat cement with up to 5% bentonite can be pressure-grouted to fill the hole. As an alternative, when the casing is not pulled, you may use course bentonite chips or pellets. If the well extends into the aquifer, the chips or pellets must be run over a screen to prevent any dust from entering the hole. No dust is allowed to enter the bore hole because of the potential for bridging. Perforation of casing is not required under this alternative.

- If the well extends into the aquifer, a clean pit-run gravel or road mix may be used to fill bore up to ten feet below top of saturated zone or ten feet below the bottom of casing, whichever is deeper, and cement grout or bentonite clay used to surface. The use of gravel may not be allowed if the lithology is undetermined or unsuitable.

- A cement cap should be placed at the top of the casing if it is not pulled, with a minimum of two feet of soil overlying the filled hole/cap.

- Abandonment of the well must be witnessed by an IDWR representative.

Financial Responsibility

No financial responsibility requirement exists for rule-authorized wells Permitted wells are required by the permit rule to demonstrate financial responsibility through a performance bond or other appropriate means to abandon the injection well according to the conditions of the permit (37.03.03.35.03.e IDAPA).

Maryland

Maryland is a Primacy State with respect to the Class V UIC program. Maryland has incorporated the federal UIC regulations (42 CFR 124, 40 CFR 144, 40 CFR 145) by reference. In addition, Maryland's Water Resources Law and regulations enacted under that law cover discharges to ground water. Ground water discharge permits are required under section 28.08 of the Code of Maryland Regulations.

Permitting

Under Maryland regulations, permits are required for any discharge of pollutants to ground water, for any industrial discharge of wastewater to a well or septic system, for any septic system with 5,000 gpd or greater capacity, and for any well that injects liquids directly into a USDW (28.08.02 CMR). Therefore, a permit is required for all aquaculture waste well discharges of one gallon or more into the environment. In addition, if aquaculture waste is discharged into a septic system, county health departments issue permits for such systems under delegated authority from the Maryland Department of the Environment (MDE). County health departments generally permit systems of less than 5,000 gpd capacity. Larger systems are permitted directly by MDE. MDE has prepared "Guidelines for Large On-Site Sewage Disposal Systems Pertaining to Onsite Community and Multiple Use Sewerage Systems With Accumulative Flow Exceeding 5,000 Gallons per Day," (March 1996) as non-binding guidance for permit applicants. The only known aquaculture waste discharge facility in the state is covered by septic system permits issued by the Maryland Department of Environment and Hartford County Health Department (Eisner, 1999; Browning, 1999).

Operating requirements

In addition to design and installation procedures, permit conditions can include monitoring and reporting requirements and general management responsibilities (Eisner, 1999).

New York

USEPA Region 2 directly implements the Class V UIC program in New York. In addition, the State Pollutant Discharge Elimination System (SPDES) requires permits for all point-source discharges into ground water. The SPDES requirement applies to all Class V wells, except septic systems of less than 1,000 gpd capacity. The only known aquaculture waste facility in the state, which is a state-run facility, has obtained a SPDES permit which covers the aquaculture discharge. Monitoring of aquaculture effluent that is discharged underground is not a requirement under this permit (Kolakowski, 1999).

Wyoming

Wyoming is a Class V Primacy State, and the Wyoming Department of Environmental Quality (DEQ) Water Quality Division has promulgated regulations pertaining to its Class V UIC Program in Chapter 16, Water Quality Rules and Regulations (WQRR). Rules on ground water pollution control permits are promulgated in Chapter 9, WQRR, but Class V wells are specifically exempted from coverage by Chapter 9 (Chapter 9 Section 3(a) WQRR). Chapter 11 of the WQRR establishes design and construction standards for disposal systems.

Permitting

Aquaculture return flow facilities (category 5E1) are covered by the General Permit provisions of the State of Wyoming's Class V rules (Chapter 16 Section 7 WQRR). A general permit is a permit issued to a class of operators, all of which inject similar types of fluids for similar purposes. General permits require less information to be submitted by the applicant than individual permits, and do not require public notice for a facility to be included under the authorization of a general permit (Chapter 16 Section 2 (l) WQRR). General permits specify the subclass of injection facility covered, the geographic area covered, the general nature of the fluids discharged, and the location of the receiver where the discharge will be allowed.

Siting and Construction

Class V facilities may not be located within 500 feet of any active public water supply well, regardless of whether or not the well is completed in the same aquifer. This minimum distance may increase or the existence of a Class V well may be prohibited within a wellhead protection area, source water protection area, or water quality management area (Chapter 16 Section 10 (n) WQRR).

A separate permit to construct is not required under Chapter 3 of the WQRR for any Class V facility. Construction requirements are included in the UIC permit issued under Chapter 16 (Chapter 16, Section 5 (v) WQRR). In order to be covered by a general permit, an operator must submit the information required by Chapter 16, Section 6 (i), (ii), and (iii), which includes a brief description of the nature of the business and activities to be conducted, information about the operator, and the location of the facility. Additional information also may be required as a condition of the general permit. The rules specify that certain construction and operating requirements must be included (see section below on operating requirements; Chapter 16 Section 10 (d) WQRR).

A facility is covered by a general permit as soon as the DEQ has issued a general statement of acceptance to allow the construction and operation of the facility (Chapter 16 Section 7 WQRR). The facility must meet general Class V construction requirements in Chapter 16 Section 10 WQRR (e.g., it must be constructed to permit the use of testing devices and allow monitoring of injected fluid quality), must meet specific construction and design requirements for sewage disposal facilities (5E) in Chapter 16 Section 10 (j) WQRR (see below), submit notice of completion of construction to the DEQ, and allow for inspection upon completion of construction prior to commencing any injection activity (Chapter 16 Section 5 (c) (i)(u) WQRR).

Operating Requirements

The general permit conditions include a requirement that the permittee must properly operate and maintain all facilities and systems, furnish information to the DEQ upon request, allow inspections, establish a monitoring program and report monitoring results, give prior notice of physical alterations or additions, and orally report confirmed noncompliance resulting in the migration of injected fluid into any zone outside of the permitted receiving zone within 24 hours and follow up with a written report within

5 days. A continuous monitoring program normally will not be required, but monitoring frequency will depend on the "ability of the facility to cause adverse environmental damage or affect human health" (Chapter 16 Section 7 (e)(v) WQRR).

The rules (Chapter 16 Section 10 (j) WQRR) also specify that all sewage disposal (5E) facilities, including aquaculture return flow facilities (5E1), shall:

- Conform to all applicable construction standards found in Chapter 11, Part D WQRR (the state's disposal system requirements, which include standards topics such as site suitability, piping material and design); and

- Comply with applicable sections of Chapter 11, Parts B and C WQRR for all piping systems or storage facilities feeding Class V facilities.

In addition, all aquaculture return flow (5E1) facilities are required to include pretreatment in a lagoon, septic tank, or oxidation ditch sized for the strength and volume of the wastes to be disposed (Chapter 16 Section 10 (k) WQRR).

Mechanical Integrity

Permittees are required to adopt measures to ensure the mechanical integrity of any well designed to remain in service for more than 60 days. No specific regulatory requirements on mechanical integrity testing have been enacted; the specific tests to be used will depend on the specific well conditions.

Plugging and Abandonment

Wells may be abandoned in place if it is demonstrated to the DEQ that no hazardous waste or radioactive waste has ever been discharged through the facility, all piping allowed for the discharge has either been removed or the ends of the piping have been plugged in such a way that the plug is permanent and will not allow for a discharge, and all accumulated sludges are removed from holding tanks, lift stations, or other waste handling structures prior to abandonment (Chapter 16 Section 12 (a) WQRR).

Financial Responsibility

Aquaculture waste disposal wells are not covered by the financial responsibility requirements in Chapter 16 WQRR.

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1. Note: According to sponsor, this product is not presently being distributed.