WASHINGTON STATE DEPARTMENT OF ECOLOGY

EFFECTS OF LEAKAGE FROM FOUR DAIRY WASTE STORAGE PONDS ON GROUND WATER QUALITY, FINAL REPORT

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ECOLOGY

EFFECTS OF LEAKAGE FROM FOUR DAIRY WASTE STORAGE PONDS ON GROUND WATER QUALITY, FINAL REPORT

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EXECUTIVE SUMMARY

Ground water quality was monitored at four dairy waste storage ponds in Washington State: two in Whatcom County, one in Yakima County, and one in Lewis County. The purpose of the monitoring was to assess whether leakage from ponds affected ground water quality.

Each pond system was underlain by shallow ground water. The ponds varied in age from new to 9 years, and construction, e.g. one-stage and two-stage pond systems. Ground water monitoring networks, consisting of an upgradient and multiple downgradient wells, were installed at each pond system. Sampling frequency varied from monthly to quarterly. Analytes included chloride, total dissolved solids, total organic carbon, chemical oxygen demand, total phosphorus, ammonia-N, nitrite+nitrate-N, and total and fecal coliform bacteria. Monitoring periods ranged from one to three years.

Leakage from three of the four ponds affected ground water quality. No leakage was detected at the fourth pond (Lewis County). At two of the leaking pond systems, downgradient concentrations were high, relative to upgradient concentrations, for nearly all parameters during most of the study period. At the third pond system, chloride, total dissolved solids, total organic carbon and chemical oxygen demand were elevated in downgradient wells. Contaminant concentrations often exceeded drinking water standards and ground water quality standards.

Concentrations of analytes varied greatly over time. At one of the new ponds downgradient concentrations increased to maximal levels about three months after the pond first received wastewater. Subsequently, concentrations decreased over time but still remained higher than the initial concentrations. This pattern suggests partial sealing of the pond. Also, the proximity of the water table and the pond bottoms may be an important factor affecting contaminant loading to ground water.

Other contaminant sources that appeared to affect ground water quality were land application of wastewater, inadvertent waste discharges, pre-existing ground water contamination, and upgradient land uses.

An inventory of ponds in Washington State located over shallow ground water is recommended to help define the extent of the problem. Additional studies are identified to fill data gaps on the effects of dairy waste management practices on ground water quality. Studies should be comprehensive and multidisciplinary to be most useful.

ACKNOWLEDGEMENTS

Many people contributed to this project. In particular, I thank the dairymen and cooperators Ed Brandsma, Cornelius Timmermans, Jacob Veldhuis, and Dan Watson. Ecology dairy waste inspectors, existing and former, assisting with the project were Diane Harvester (SWRO), Max Linden (CRO), Harold Porath (CRO), Bob Wright (NWRO). Ecology regional hydrogeologists that assisted were Dave Garland (NWRO) and Cyronose Spicer (SWRO). Bernie Strong and Pam Marti (EILS) assisted with well installation, soil sampling and ground water sampling. Dr. Ron Hermanson with Washington State University provided pertinent literature. Ecology peer reviewers for this report and/or individual pond reports were Larry Goldstein, Bill Yake, Pam Marti, Art Larson, Greg Pelletier, and Randy Coots of EILS Program; Dave Garland, Cyronose Spicer, Bob Raforth, Harold Porath, Phil KauzLoric and Melanie Kimsey of the Water Quality Program. Pam Covey, Craig Smith and Dave Thompson, Manchester Laboratory, tracked sample flow and assured quality analytical results. Kelly Carruth formatted and edited the reports. Dick Wallace and Nancy Winters, Water Quality Program, provided financial support. Bob Monn, formerly of the Water Quality Program, conceived the need for the project. Lynn Singleton and Mike Llewelyn, Ecology Program Managers, provided the long term commitment to complete the project.

INTRODUCTION

Washington State has about 1100 active, commercial dairies (Department of Agriculture, 1993). Based on a survey of 675 dairies in northeast Puget Sound, at least half of the dairies have a waste storage pond (Bachert, 1993). Waste storage ponds temporarily store manure and wastewater during winter when: 1) nutrient uptake by cover vegetation and crops is low, and 2) the potential for surface runoff and ground water contamination from land application of wastes is high. In summer, ponds store dairy wastes between field spray applications. The capacity of waste storage ponds and the periods of storage vary widely by farm.

Waste storage ponds may leak if not properly sealed and may contaminate ground water. However, studies indicate that waste storage ponds are to some degree self-sealing and that leakage rates decrease substantially after ponds are initially filled (Reese and Loudon, 1983). Research suggests that at least a partial seal, consisting of settled solids, a microbial layer, or a combination of both, limits leakage from ponds. Reese and Loudon concluded that leakage rates and the rates of sealing appear to be a function of soil texture (pore size), total solids concentration, and hydraulic head. There is general consensus among researchers that leakage rates decrease after ponds first receive wastewater. There is disagreement, however, on seal efficacy and whether the leakage is a threat to ground water quality.

Purpose

The purpose of this study was to assess whether leakage from dairy waste storage ponds in Washington State affected ground water quality. Four dairies with pond systems were selected: two in Whatcom County, one in Yakima County, and one in Lewis County. Each of the pond systems was constructed over shallow ground water. Results for the first year of monitoring were described in individual reports for each dairy (Erickson 1991, 1992a, 1992b, 1992c). Monitoring was continued an additional two years at the three ponds showing leakage. For detailed information and site descriptions for each pond system, refer to these individual reports.

This report has two objectives:

- to combine all results from the four dairies into one report, and
- to summarize overall findings of the study.

Site conditions, water level results, and water quality results for each of the dairies are discussed separately. Discussion, Conclusion and Recommendation Sections of this report present overall findings.

Locations

The locations of the four dairies are shown in Figure 1. Whatcom Dairy #1 was located in northern Whatcom County about 15 miles north of Bellingham and three miles north of Lynden. Whatcom Dairy #2 was located about three miles southwest of Whatcom Dairy #1.

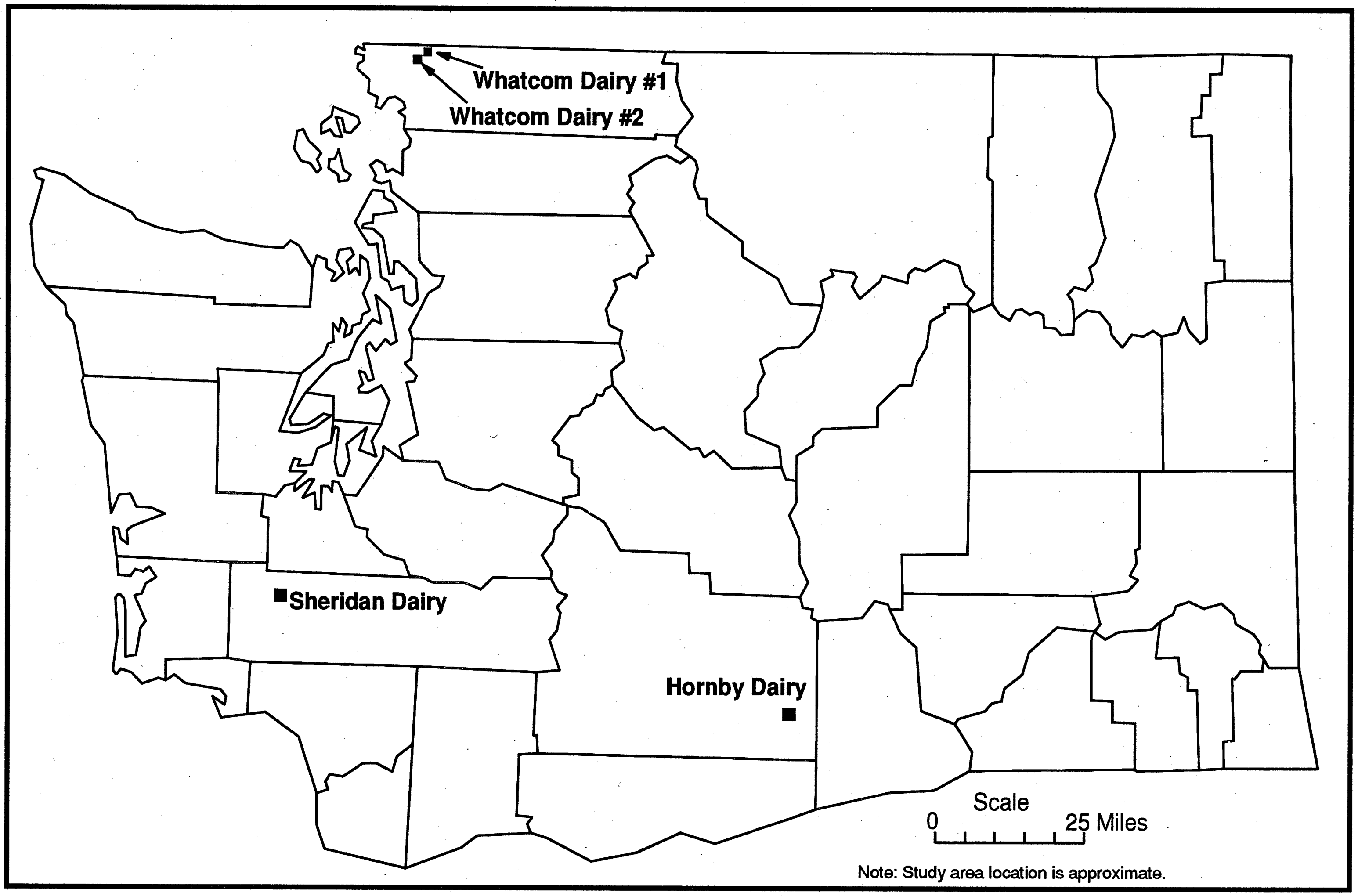

Figure 1. Dairy Location Map

Hornby Dairy was located in Yakima County about 35 miles southeast of Yakima and three miles southeast of Sunnyside. Sheridan Dairy was located in Lewis County about five miles west Chehalis.

METHODS

A ground water monitoring network was installed at each pond system to obtain water quality samples and to define directions and rates of ground water flow. Also, wastewater samples were collected at the pond surface. Samples were tested for ammonia-N, nitrate+nitrite-N, total phosphorus, total organic carbon (TOC), chemical oxygen demand (COD), total dissolved solids (TDS), chloride, and total and fecal coliform bacteria.

Total persulfate nitrogen (TPN), a measure of total (inorganic and organic) nitrogen, was tested in a few samples. Testing for TPN was stopped because results were inconsistent with, and less than, total inorganic nitrogen concentrations for samples with high concentrations of dissolved constituents (Erickson, 1991).

Well Installation and Water Levels

Monitoring wells were constructed with 1¼-inch diameter galvanized pipe and 2-foot-long, stainless steel wellpoints. Well screens and casing were steam cleaned prior to installation. Bentonite surface seals were installed at each well by augering an oversized hole, about six inches in diameter and three feet deep, and placing hydrated 1/2-inch bentonite pellets in the annular space. After the wellpoint was driven past the bottom of the oversized hole, hydrated bentonite was added to the annular space during driving of the remaining casing to the desired well depth. Wells were developed by surging with a one-way foot valve attached to 3/4-inch PVC pipe or pumping with 1/3 HP centrifugal pump. Well construction data for each study site are listed in Appendix B.

Well water levels were measured each sampling event using an electric well probe. Relative elevations of measuring points for the monitoring wells were determined using a surveyor's level and rod. All elevations were measured relative to temporary bench marks (TBMs) established for each site. The TBMs were assigned mean sea level elevations from USGS 7.5 minute topographic maps. Relative elevations of measuring points are accurate to 0.05 feet. Water level data for each study site are listed in Appendix C.

Sampling and Analysis

Wells were purged and sampled using a peristaltic pump attached to dedicated 3/8-inch ID polyethylene tubing. Flexible silastic tubing was used in the peristaltic pump head. Prior to sampling, wells were purged a minimum of three well volumes and until pH, temperature, and specific conductance measurements had stabilized. Measurements were considered stable when the change between well volumes was less than 0.1 Standard Units for pH, 0.2°C for temperature, and 20 micromhos/cm for specific conductance. At Hornby Dairy, wells were purged only one to two well volumes prior to sampling because of the slow recharge rate. Grab samples from the ponds were collected just below the wastewater surface. All samples were placed in coolers with ice and transported to the Ecology/EPA Region X Laboratory in Manchester, Washington. The parameters tested, test methods, and method detection limits are listed in Appendix A.

Monitoring of Whatcom Dairy #1 covered three years, from February 1990 through April 1993. Wells were sampled monthly the first year and about quarterly thereafter. The monitoring network at Whatcom Dairy #2 was sampled quarterly between February 1991 and April 1993. Wells at Hornby Dairy were sampled quarterly from April 1990 to March 1993. At Sheridan Dairy wells were sampled quarterly for one year between June 1991 and April 1992. At the end of one year monitoring was stopped because vertical flow rates from the pond to the aquifer through underlying silt and clay deposits were low.

Quality Assurance

In general the quality of the data is good and is considered acceptable for use. Exceptions are qualified on the results tables (Appendix F) and discussed in Appendix D.

Whatcom Dairy #1 and its pond system were constructed in the fall of 1989 to handle manure and wastewater from 900 cows. The two-stage pond system consisted of a primary settling pond (2.4 million gallons) and a secondary main pond (10.4 million gallons). The settling pond first received manure and wastewater March 1, 1990; the main pond was prematurely flooded with liquid manure May 3, 1990 when the embankment separating the settling pond from the main pond inadvertently was breached. Based on Soil Conservation Service (SCS) engineering cross sections, the main pond system was excavated about 8 feet below the ground surface and may have intersected the water table. The settling pond was 2.9 feet deeper than the main pond. The berm was repaired in September 1990 by dewatering both ponds. Topsoil was reportedly amended to portions of the bottom of the main pond during the repair work.

The pond system was constructed over a water-table aquifer consisting of glacial outwash deposits of stratified sand and gravel (Easterbrook, 1971). The aquifer was about 40 to 50 feet thick. The water table, which fluctuated seasonally four to ten feet due to variations in precipitation, irrigation and pumping, was less than ten feet below ground surface. The relationship of the pond and site hydrogeology is shown in Figure 2. Ground water flow velocity was estimated from chloride travel times to be about one to two feet per day (Erickson, 1991).

The monitoring network consisted of eight monitoring wells: one upgradient well (MW5), four wells 40-feet downgradient of the ponds (MW1 through MW3 and MW6A), two wells about 170 feet downgradient of the ponds (MW4 and MW7A), and one well about 1800 feet downgradient (MW8). The well locations are shown in Figure 3. The network was installed before the ponds received wastewater. Well depths ranged from 11.6 to 18.6 feet.

Water Levels

The fluid level of the ponds, largely controlled by wastewater production and land application, coincidentally mimicked fluctuations of the local ground water table, that is, low in the summer and high in the winter. Hydrographs for the pond and wells MW3, MW4, and MW5 and are shown in Figure 4. Also, monthly precipitation totals are shown along the bottom horizontal axis in Figure 4. The hydraulic potential of both the settling pond and the main pond was always higher than the water table. Therefore, the potential for downward migration of contaminants existed throughout the year. Water-table contour maps, constructed using monitoring water levels, showed no evidence of water-table mounding due to leakage from the ponds (Erickson, 1991).

The proximity of the pond bottoms to ground water (separation distance) varied seasonally because of the fluctuating water table. The separation distance at the main pond was about four feet in fall and early winter and about two feet in late winter and spring. During November and December 1990, the water table was higher than the bottom of the pond.

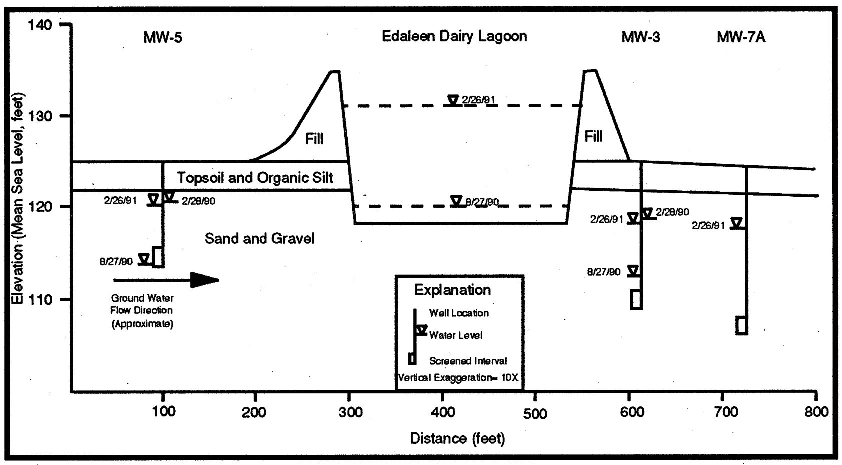

Figure 2. Whatcom Dairy #1, North-South Hydrogeologic Profile

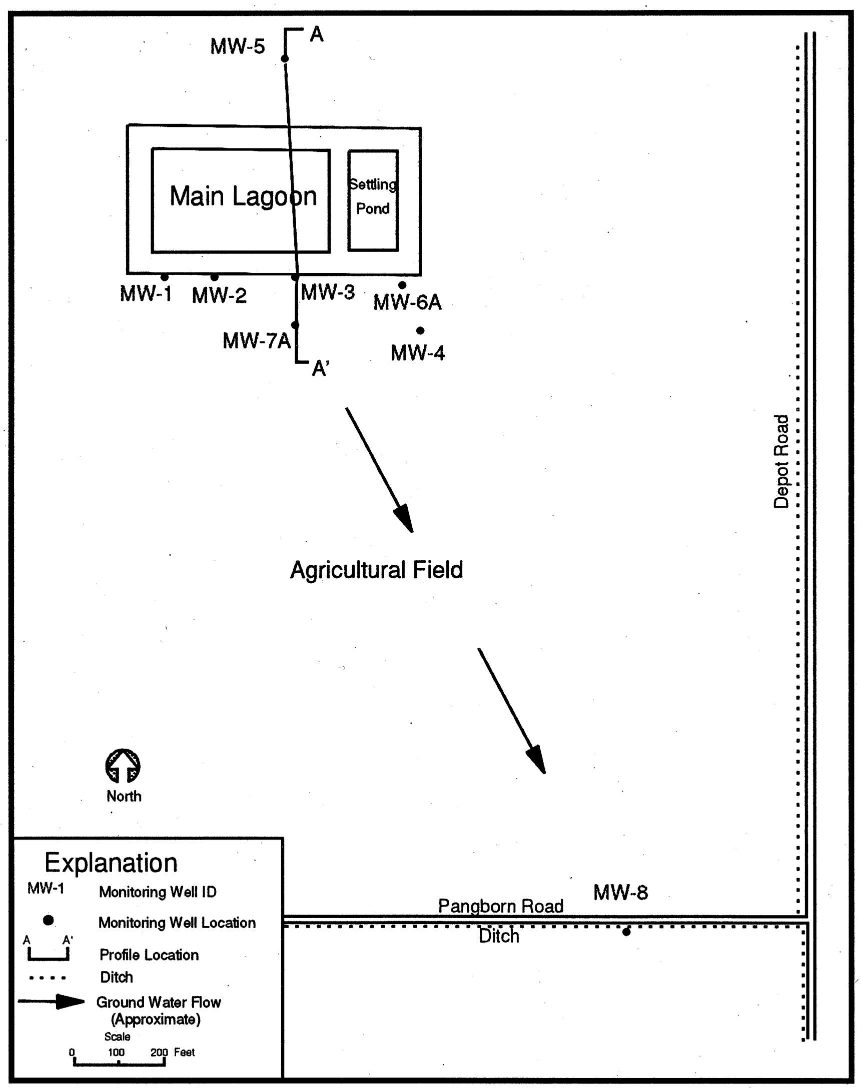

Figure 3. Whatcom Dairy #1, Monitoring Well Locations.

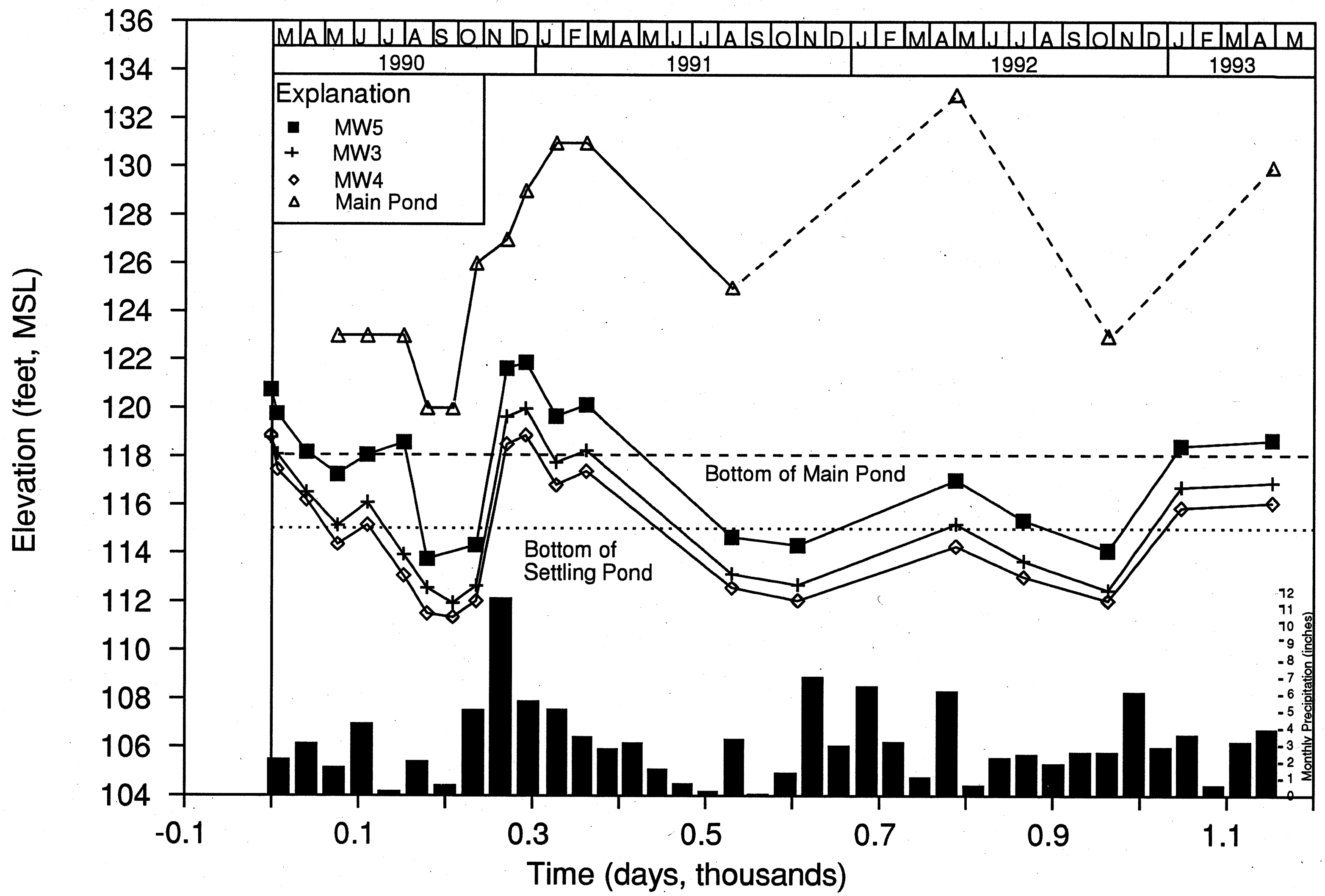

Figure 4. Hydrographs, Whatcom Dairy #1 and Bellingham Monthly Precipitation.

Nearly 12 inches of precipitation in November 1992 probably caused the elevated water table. At the settling pond, which is about three feet deeper than the main pond, the water table was typically higher than the pond bottom in late-winter and early spring.

Water Quality

Water quality results for Whatcom Dairy #1 are shown in Appendix F, Tables F-1 (Water Chemistry) and F-2 (Bacteriology and Miscellaneous). Chloride, total dissolved solids (TDS), ammonia-N, nitrate+nitrite-N, and total phosphorus, chemical oxygen demand (COD), and total organic carbon (TOC) concentrations are graphed over time in Figures 5 through 11. For clarity, only selected wells are shown on the figures. The results for specific parameters are discussed below. Findings are summarized in section "Summary of Whatcom Dairy #1" following the discussion of specific parameters.

Chloride

Overall, chloride concentrations downgradient of the settling pond were consistently higher than concentrations downgradient of the main pond. Even before the settling pond received wastewater chloride concentrations downgradient of the settling pond were higher (49 mg/L) than upgradient concentrations. These higher concentrations were not related to pond usage but are due to some previous land use. Nevertheless, concentrations downgradient of the settling pond increased substantially after the pond received wastewater. Unlike the main pond, however, chloride concentrations did not decrease with time; instead they fluctuated seasonally with maximum concentrations of over 100 mg/L observed in October 1991 and 1992.

Wastewater chloride concentrations ranged from 199 to 399 mg/L. After the main pond received wastewater, downgradient chloride concentrations increased from an initial 5 to 10 mg/L and peaked at about 110 mg/L in August 1990 (about 3 months after the main pond received wastewater). Chloride decreased over the final two years to 45 mg/L. Concentrations downgradient of the main pond were consistently higher than upgradient concentrations until the last sampling event in April 1993.

Upgradient chloride concentrations (MW5) increased during the study period. During the first eight months, chloride concentrations in MW5 ranged from about 2 to 11 mg/L. The concentrations began to increase in November 1990, peaked in January 1991 at about 50 mg/L, and then decreased to about 15 mg/L. After March 1992 the chloride concentrations increased gradually to about 50 mg/L in April 1993. The cause of the increase was likely due, in part, to land application of wastes to the field where MW5 was installed.

Total Dissolved Solids (TDS)

TDS concentrations in ground water were highest downgradient of the settling pond. As with chloride, TDS concentrations downgradient of the settling pond were higher than

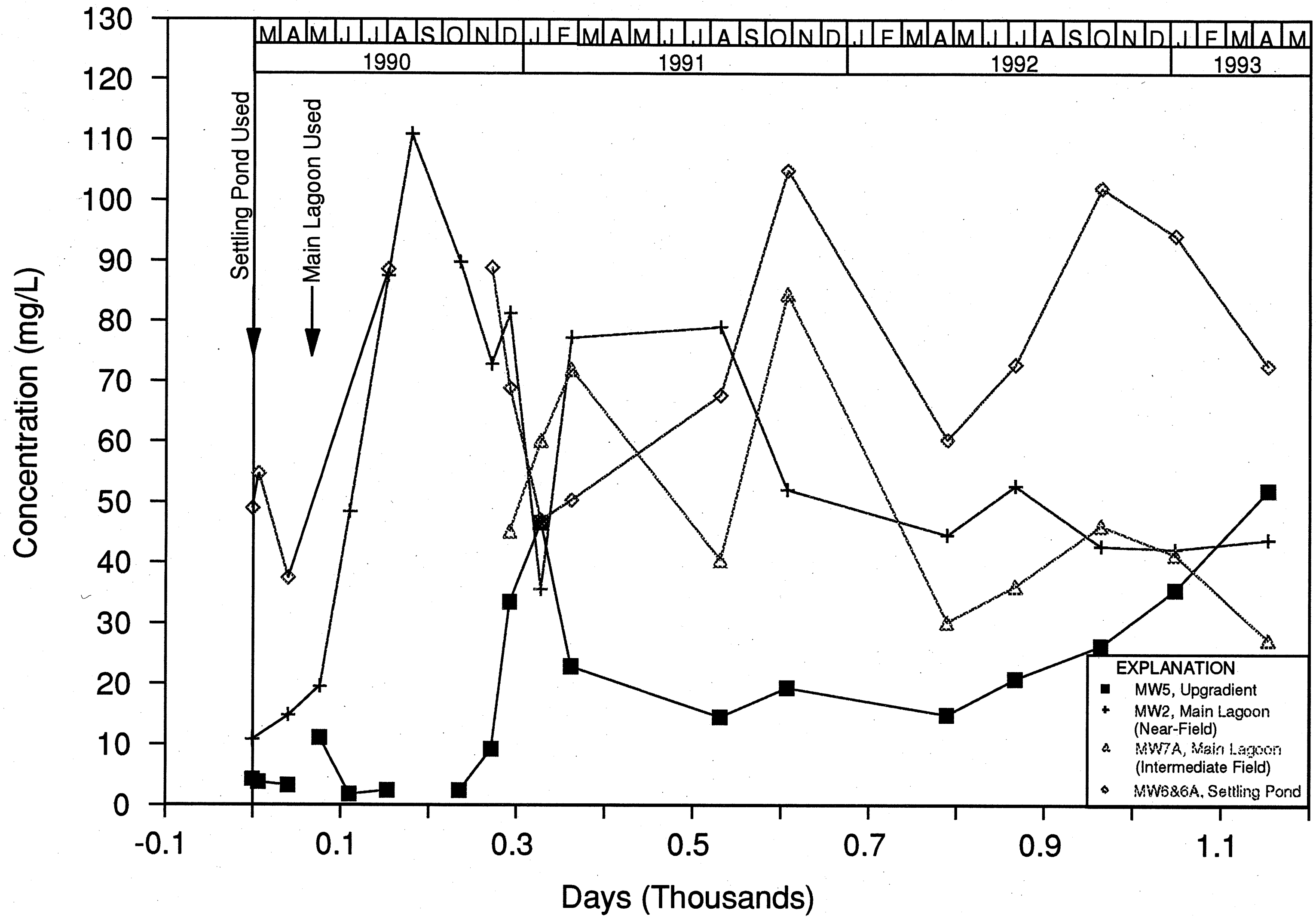

Figure 5. Whatcom Dairy #1, Chloride Results.

upgradient concentrations at the onset of monitoring (Figure 6). TDS concentrations in monitoring wells varied seasonally with peaks of 1130 and 1160 mg/L occurring in October 1991 and 1992, respectively.

TDS concentrations in wastewater ranged from 2890 to 6850 mg/L. In ground water downgradient of the main pond, TDS concentrations initially ranged between 200 and 400 mg/L. TDS peaked in August 1990 at 1640 mg/L (three months after the main pond received wastewater) and then decreased during the remainder of the study period. Upgradient TDS concentrations generally increased over the study period from initial concentrations of about 140 to 160 mg/L to 851 mg/L in April 1993.

Nitrogen

The primary nitrogen species observed in wastewater and downgradient ground water was ammonia. Ammonia-N concentrations in the wastewater ranged from 275 to 589 mg/L. Ammonia-N concentrations in ground water are graphed over time in Figure 7. Upgradient concentrations were generally less than 0.1 mg/L and always less than 4 mg/L. Downgradient of the main pond, ammonia-N increased to a peak concentration of 142 mg/L in August 1991 (15 months after the main pond received wastewater) and decreased to about 60 mg/L by April 1992. Thereafter, the concentration remained relatively constant.

Even before the settling pond received wastewater, downgradient ammonia-N concentrations were higher (30 mg/L) than upgradient concentrations. After the settling pond received wastewater, downgradient ammonia-N concentrations increased. Concentrations fluctuated seasonally over a range of about 100 mg/L. The highest ammonia-N concentrations at the site were observed downgradient of the settling pond. Peak concentrations, observed in October 1991 and 1992, were 160 and 184 mg/L, respectively.

In contrast to the other parameters, nitrate+nitrite-N concentrations decreased downgradient of the pond. Presumably the lower concentrations were due to denitrification. Under anaerobic conditions nitrate (NO3) is reduced (denitrified) first to nitrite (NO2), then nitrogen gas. However, upgradient of the ponds nitrate+nitrite-N concentrations increased during the study period. Concentrations were less than 10 mg/L from March to October 1990; increased to a maximum of 99 mg/L (January 1991); decreased to about 20 mg/L (August 1991); and then gradually increased to 91 mg/L in April 1993, the end of the study.

Total Phosphorus

Total phosphorus concentrations in wastewater ranged from 26 to 133 mg/L. Concentrations in selected wells are graphed in Figure 9. With one exception (0.31 mg/L in October 1990) upgradient concentrations were generally less than 0.05 mg/L. For the most part concentrations were higher downgradient of the ponds. Downgradient of the main pond, total phosphorus peaked (0.28 mg/L) in November 1990 and generally decreased to about 0.1 mg/L. Concentrations downgradient of the settling pond peaked in the fall of 1990 at

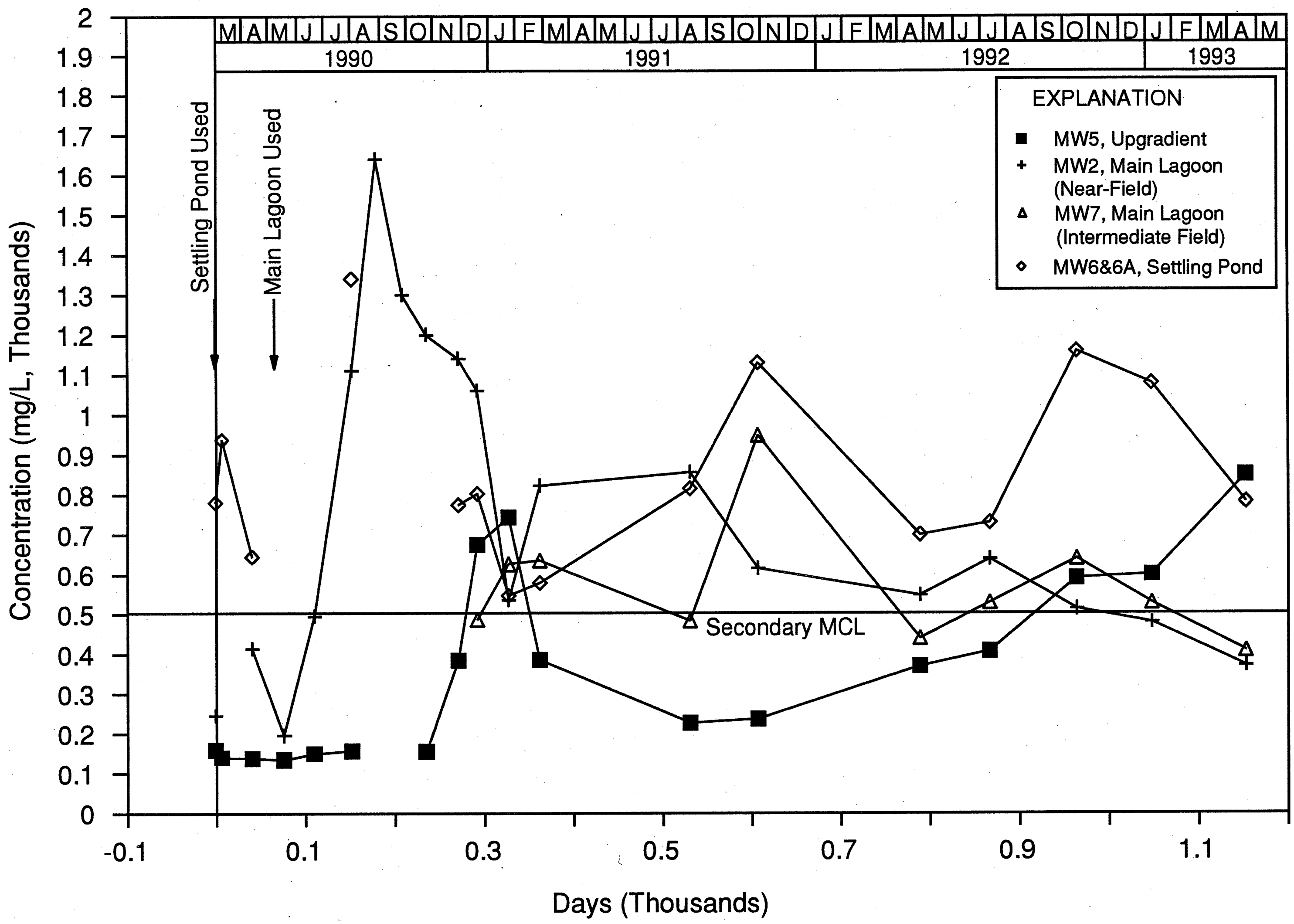

Figure 6. Whatcom Dairy #1, Total Dissolved Solids.

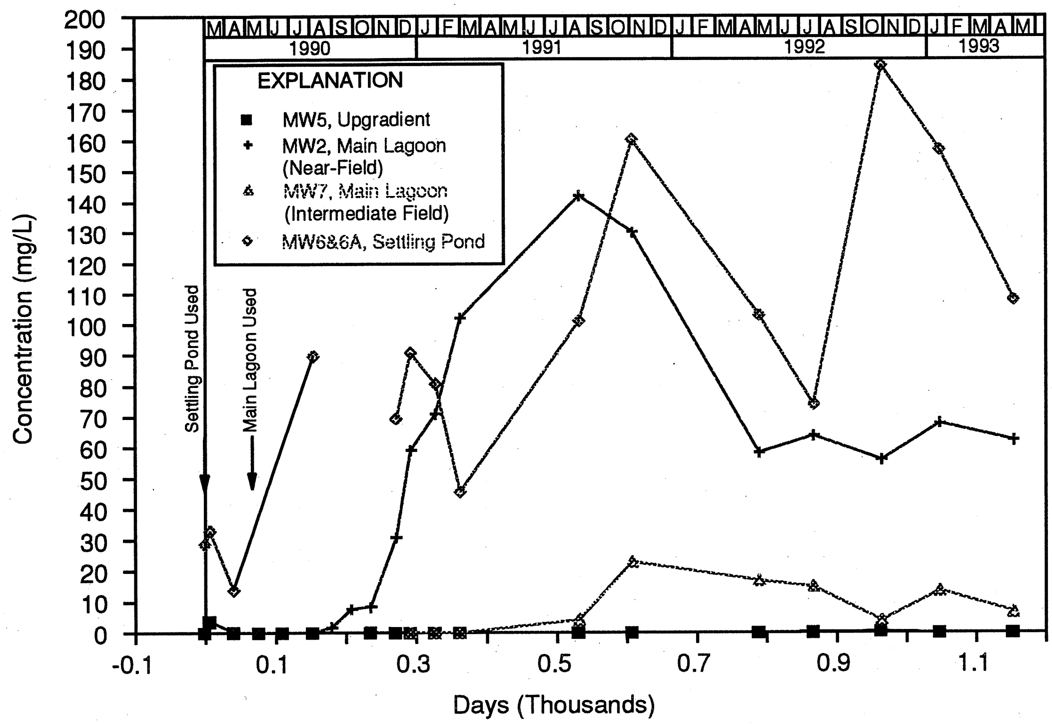

Figure 7. Whatcom Dairy #1, Ammonia-N.

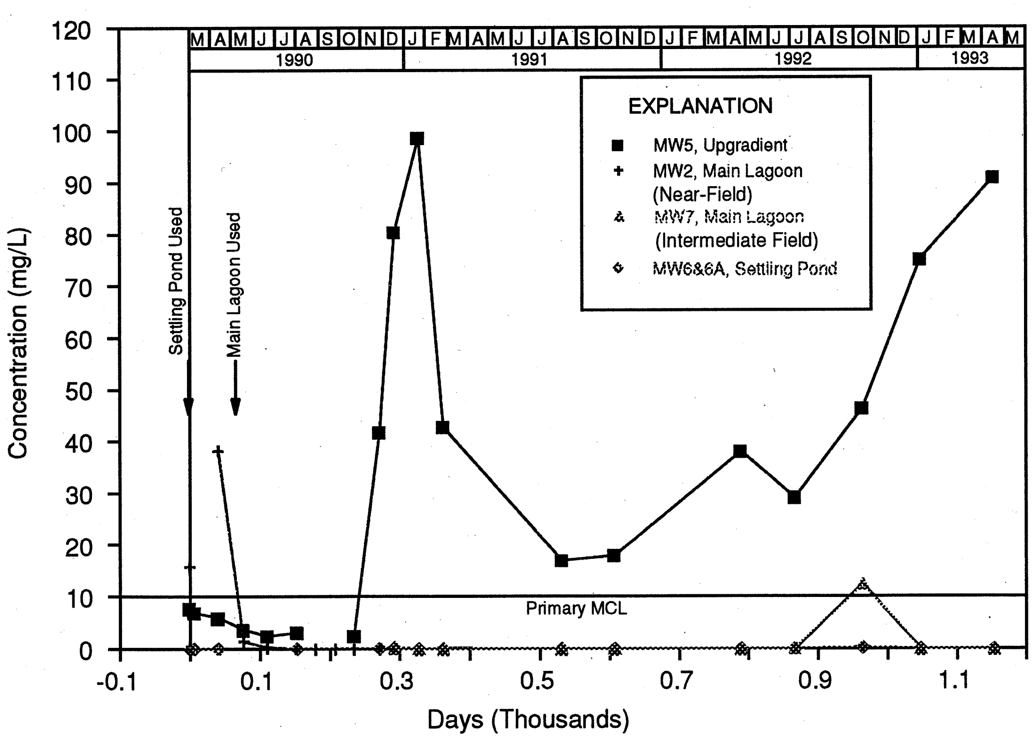

Figure 8. Whatcom Dairy #1, Nitrate+Nitrite-N.

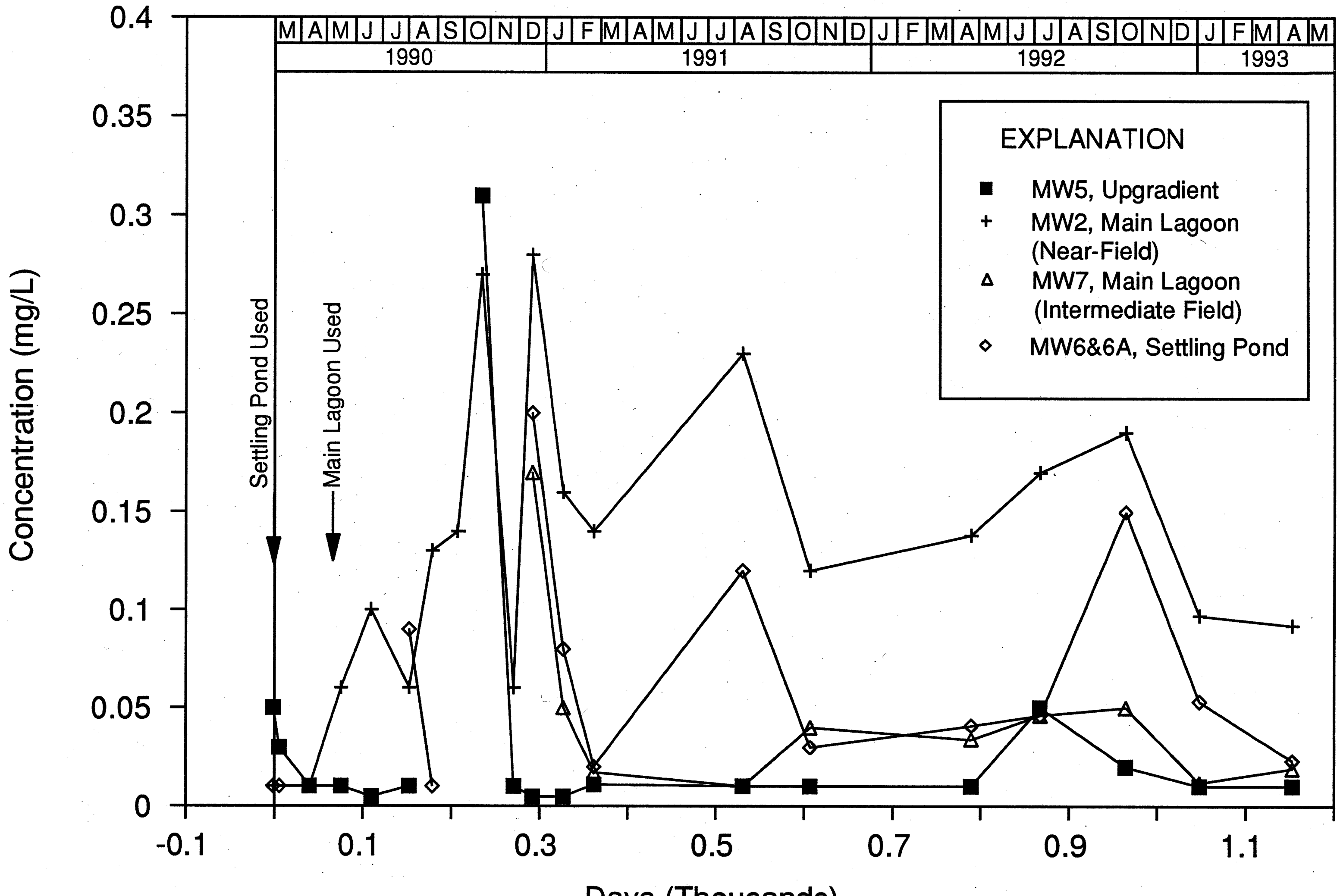

Figure 9. Whatcom Dairy #1, Total Phosphorus.

0.20 mg/L but varied seasonally with highs in August 1991 (0.12 mg/L) and October 1992 (0.15 mg/L) and lows (less than 0.05 mg/L) in winter and spring.

Chemical Oxygen Demand and Total Organic Content

In wastewater COD concentrations ranged from 1,300 to 14,600 mg/l and TOC concentrations ranged from 974 to 2,880 mg/L. COD and TOC concentrations in selected wells are graphed in Figures 10 and 11.

COD and TOC upgradient concentrations typically were less than 10 mg/L and 8 mg/L respectively. Downgradient of the main pond concentrations peaked at 1064 mg/L and 429 mg/L, respectively, in August 1990 (three months after the main pond received wastewater). The concentrations decreased rapidly over the next three months and then decreased gradually during the remainder of the study period to COD 62 mg/L and TOC 21.5 mg/L.

Downgradient of the settling pond, concentrations increased to highs of 870 mg/L COD and 359 mg/L TOC in August 1990 and decreased over three months to about 100 to 300 mg/L COD and 50 to 150 mg/L TOC. After December 1990 concentrations, although fluctuating seasonally with peaks in October 1991 and 1992, were generally stable. At the end of the study period (April 1993), concentrations were still substantially higher than upgradient (COD 124 mg/L and TOC 49 mg/L).

Coliform Bacteria

Total coliform and fecal coliform bacteria, present in high concentrations in the wastewater (440,000 to 8,600,000 and 230,000 to 5,800,000 CFU/100ml, respectively) were rarely observed in ground water. Only one sample (MW2, January 1991) had a substantial density (148 CFU/100ml) of total coliform bacteria.

Summary of Whatcom Dairy #1

After ponds received wastewater, downgradient concentrations of chloride, TDS, TOC, COD, total phosphorus and ammonia-N substantially increased. In general, concentrations downgradient of the main pond reached maximal concentrations about three months after receiving wastewater, decreased rapidly over three to four months and then decreased gradually for the remaining two years of the study. However, concentrations at the end of the study remained higher than initial and upgradient concentrations. This pattern suggests a high leakage rate after the ponds were first used followed by a lower leakage rate.

Even before the settling pond received wastewater, downgradient concentrations were higher than upgradient concentrations. The source of this pre-existing contamination is not known. Concentrations downgradient of the settling pond increased after the pond was first used. However, unlike the main pond, concentrations did not decrease with time. Instead

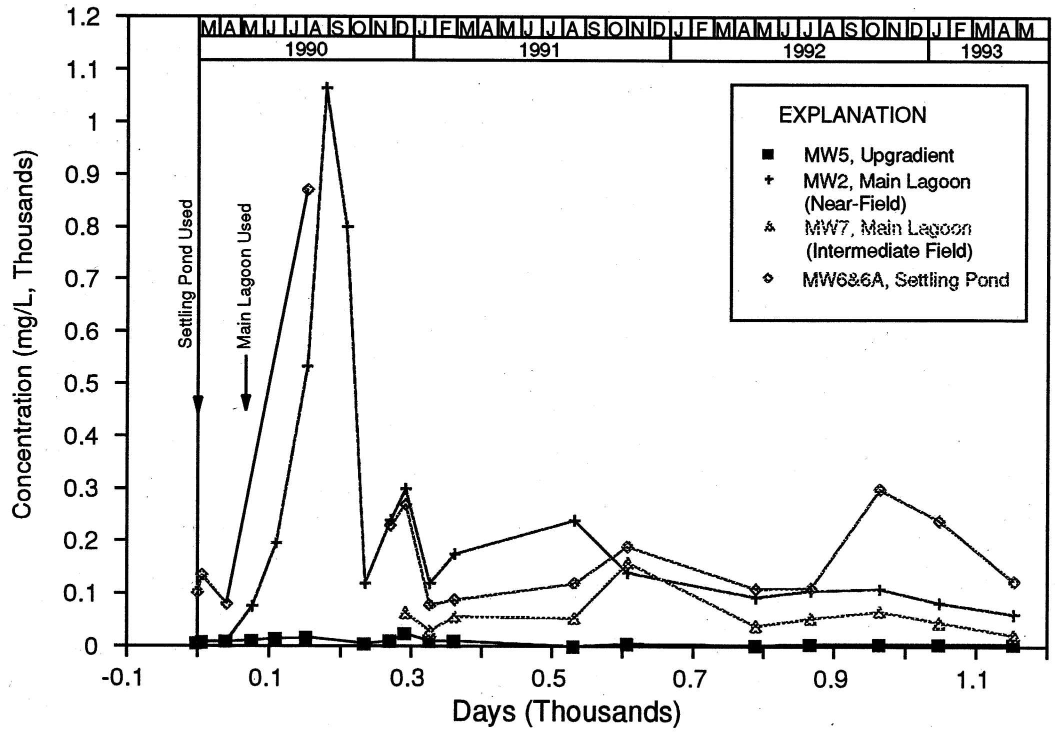

Figure 10. Whatcom Dairy #1, Chemical Oxygen Demand (COD).

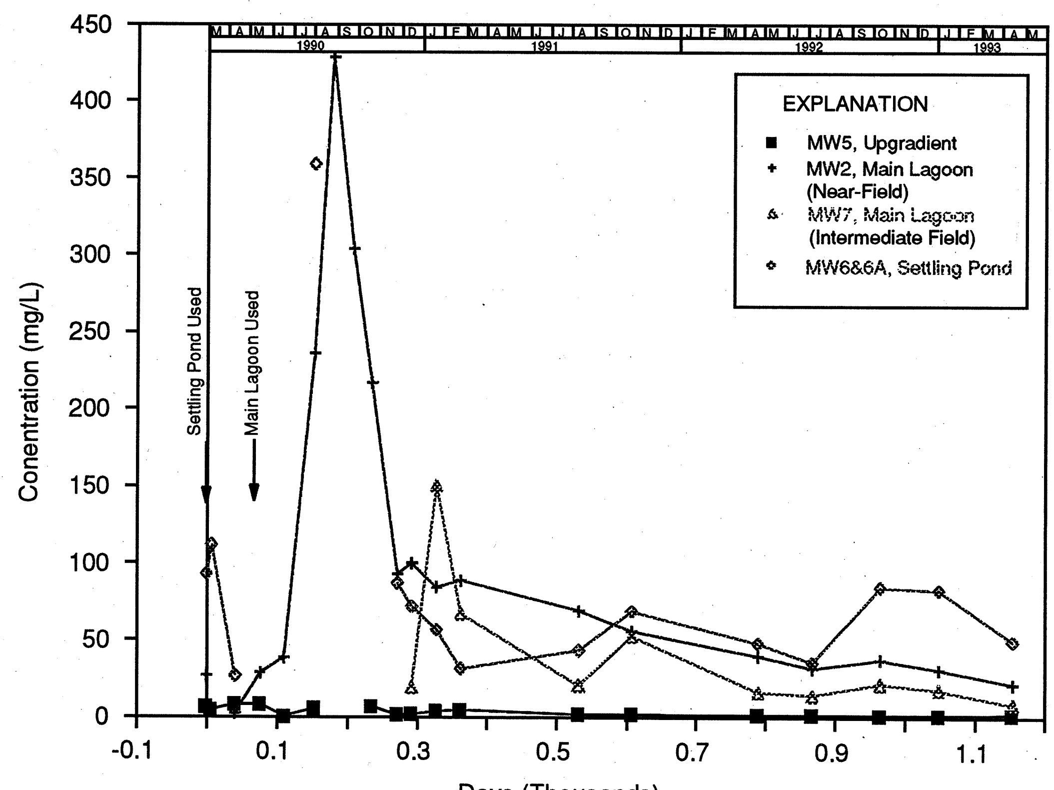

Figure 11. Whatcom Dairy #1, Total Organic Carbon (TOC).

concentrations fluctuated seasonally and, over the long term, appeared to be increasing or remaining the same. Maximum concentrations occurred in the fall (October) and minimum concentrations occurred in spring.

The proximity of the water table to the pond bottoms (separation distance) may account for the seasonal variation of concentrations downgradient of the settling pond. Separation distance fluctuated seasonally due to the rising and falling of the water table (Figure 4). Of particular importance were the times when the water table directly contacted the pond bottom, that is, the separation distance was less than zero. The water table was above or close to the bottom of the settling pond in late winter and early spring. In general, high contaminant concentrations were observed in ground water downgradient of the settling pond about six to ten months after the water table contacted the pond bottom or was high. In contrast, the separation distance beneath the main pond over the last two years of the study ranged from about two to four feet. Over that time concentrations downgradient of the main pond decreased.

Ground water quality in the area also was affected by land-use practices other than the ponds. Upgradient (MW5) concentrations of TDS, nitrate+nitrite-N and chloride varied substantially over time. These variations were most likely related to land application of wastes, possibly combined with heavy precipitation. By the end of the study, upgradient concentrations of chloride and TDS increased and were at least as high as concentrations downgradient of the main pond.

Upgradient concentrations of total phosphorus, COD and TOC did not increase substantially over the study period. Concentrations for these parameters downgradient of the main pond were higher than upgradient concentrations at the end of the study period.

WHATCOM DAIRY #2

The single stage pond at Whatcom Dairy #2, originally constructed in 1980 and widened in 1989, was designed to handle manure and wastewater for 420 cows and had a capacity of 2.5 million gallons. Prior to 1989, manure and wastewater were stored in the pond. After 1989, manure solids were separated from the waste and were land applied.

The pond was constructed over a water-table aquifer consisting of glacial outwash deposits of stratified sand and gravel. The relationship of the pond and site hydrogeology is shown in Figure 12. The aquifer was about 40 to 50 feet thick. Depth to the water table ranged between five and nine feet and fluctuated seasonally due to variations in precipitation, pumping, irrigation and infiltration from ditches. Hydraulic gradients range from 0.001 to 0.004 (foot/foot) and Erickson (1992b) estimated the ground water flow velocity to be about one foot/day.

The monitoring network consisted of six monitoring wells (Figure 13): two upgradient wells (MW1 and MW5) to define upgradient ground water quality, three downgradient wells (MW2, MW3 and MW4) about 40 feet from the pond, and one downgradient well (MW6) about 190 feet from the pond. Monitoring well depths ranged from 14 to 18 feet. MW1 was inadvertently destroyed midway through the study and was replaced with MW5 in July 1992. The monitoring network was sampled quarterly between February 1991 and April 1993.

Water Levels

Ground water levels fluctuated two to four feet over the study period and the waste storage pond level fluctuated about six feet (Figure 14). The fluid level in the pond was three to seven feet higher than ground water. Therefore, the potential for vertical downward migration of contaminants existed throughout the year. The separation distance between the bottom of the pond and the water table was generally less than two feet. The separation distance ranged from minus two feet (the water table was two feet higher than the pond bottom) in December 1992 through February 1993 to two feet. The separation distance was greatest in the fall when the water table was lowest.

Water Quality

Water Quality results are shown in Appendix F. Chemistry and bacteriologic results are listed in Tables F-3 and F-4, respectively. The results of specific parameters are discussed below. Findings are summarized in section "Summary of Whatcom Dairy #2" following the discussion of specific parameters.

<u>Chloride</u>

Chloride was present in wastewater at concentrations ranging from 342 mg/L to 645 mg/L. Chloride concentrations over time are graphed in Figure 15. In general, downgradient

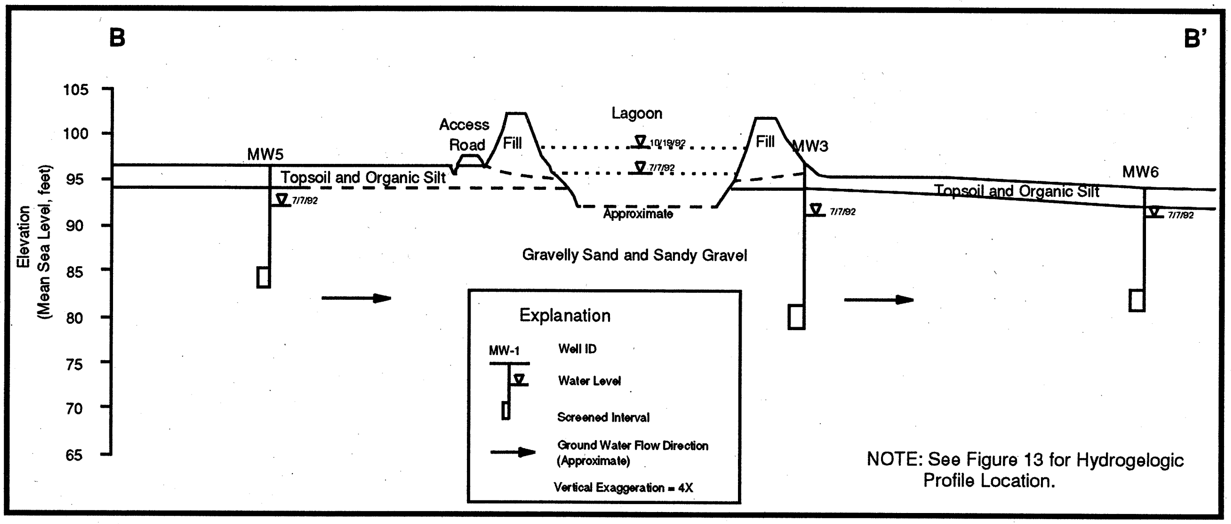

Figure 12. Whatcom Dairy #2, Hydrogeologic Profile.

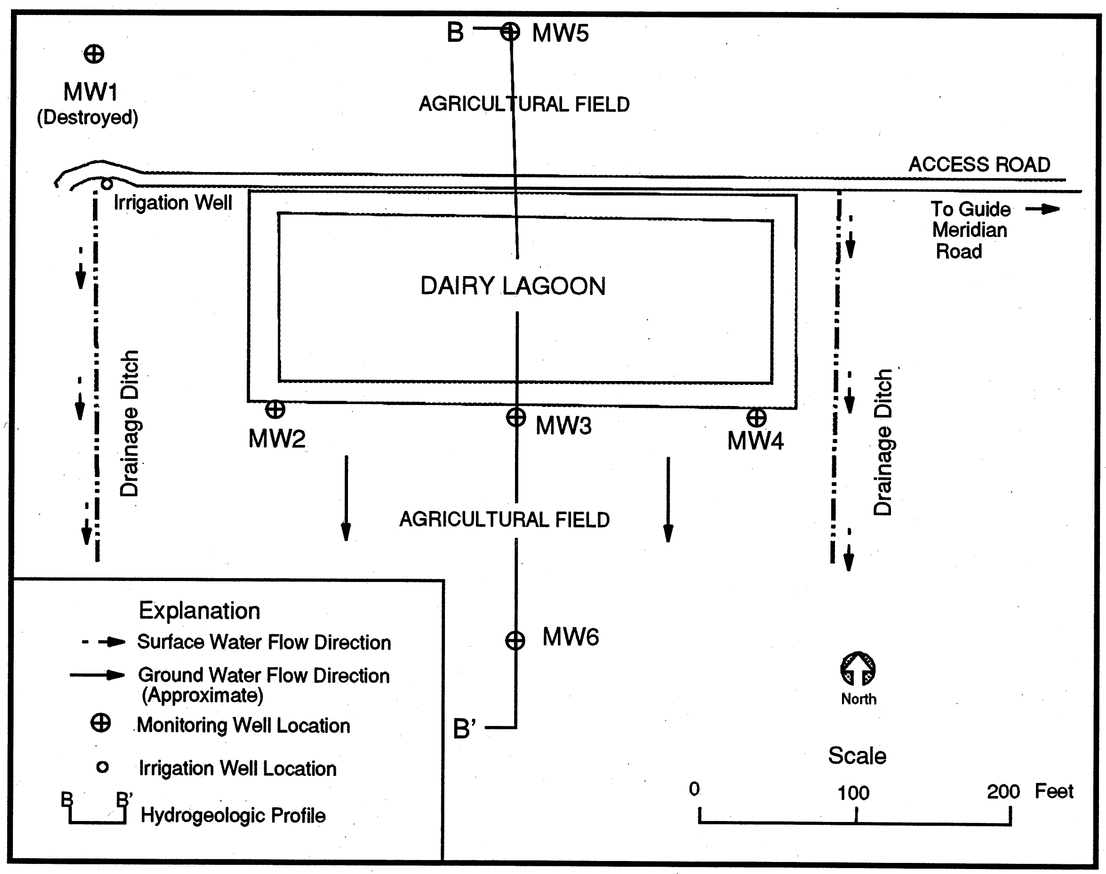

Figure 13. Well Location Map, Whatcom Dairy #2.

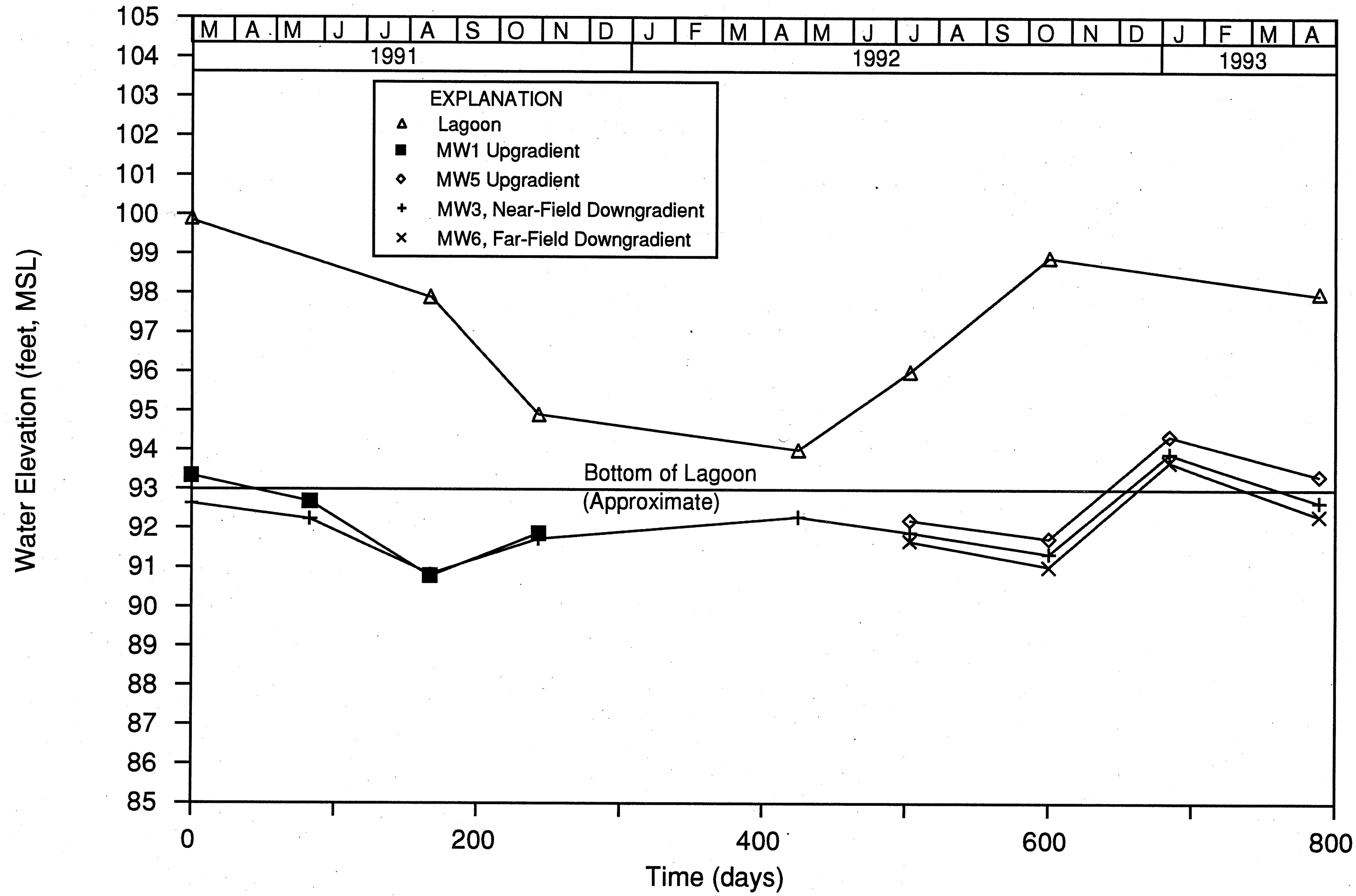

Figure 14. Hydrographs, Whatcom Dairy #2.

concentrations were much higher than upgradient concentrations (MW1 and MW5). Upgradient ground water concentrations ranged from 4.0 to 6.7 mg/L. Chloride concentrations in downgradient wells were higher, ranging from 7.8 to 145 mg/L. Concentrations at MW2 and MW4 fluctuated widely during the first year of monitoring but variations decreased over the remainder of the study period. The maximum chloride concentration, 145 mg/L, was observed at MW4 in May 1991.

Total Dissolved Solids(TDS)

The TDS concentrations in wastewater ranged from 7,760 to 38,900 mg/L. TDS concentrations in wells are graphed in Figure 16. Upgradient concentrations typically were about 300 mg/L. Concentrations downgradient of the pond were generally higher ranging from 300 to 550 mg/L. The maximum TDS concentration, 1420 mg/L, was observed at MW4 in May 1991.

Nitrogen

The most abundant form of nitrogen observed was ammonia-N. Concentrations of ammonia-N in wastewater ranged from 400 to 1,100 mg/L. Ammonia-N concentrations in wells are shown in Figure 17. Concentrations upgradient of the pond ranged from 0.2 to 0.3 mg/L. Concentrations downgradient of the pond were generally higher ranging from 10 mg/L to greater than 100 mg/L. The maximum ammonia-N concentration, 180 mg/L, was observed at MW4 in May 1991.

Nitrate+nitrite-N concentrations were typically less than the detection limit (0.01 to 0.05 mg/L) upgradient and downgradient of the pond.

Total Phosphorus

Wastewater concentrations of total phosphorus ranged from 21 to 1900 mg/L. Total phosphorus concentrations in wells are shown in Figure 18. Concentrations upgradient of the pond ranged from 0.01 to 0.09 mg/L. Downgradient concentrations were higher ranging from 0.2 to 4 mg/L. Concentrations at MW6 (2.6 to 6.4 mg/L), located about 190 feet downgradient of the pond, were higher than concentrations in downgradient wells near the pond over the last year of monitoring. The maximum total phosphorus concentration, 20 mg/L, was observed at MW4 in May 1991.

Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC)

COD and TOC concentrations in wastewater ranged from 540 to 46,000 mg/L and 382 to 9430 mg/L, respectively. COD and TOC concentrations in wells are shown in Figures 19 and 20.

Upgradient COD concentrations were generally less than 10 mg/L. Downgradient of the pond COD concentrations were higher, ranging from 10 to 80 mg/L. Upgradient TOC

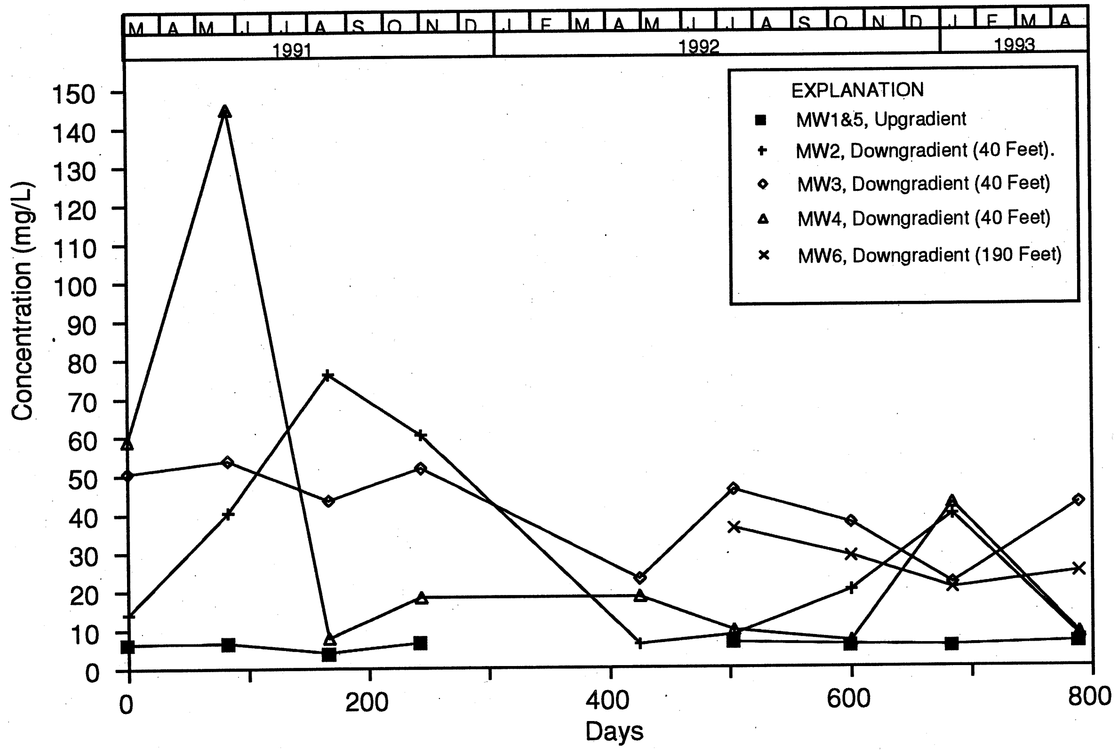

Figure 15. Whatcom Dairy #2, Chloride.

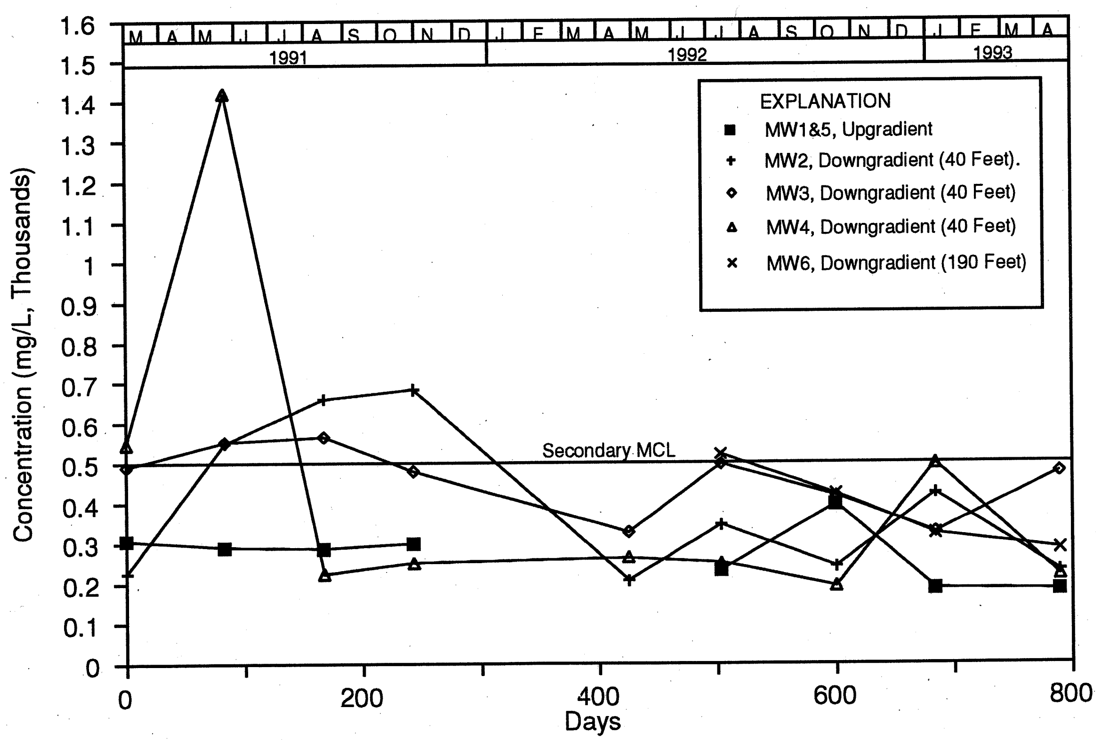

Figure 16. Whatcom Dairy #2, Total Dissolved Solids.

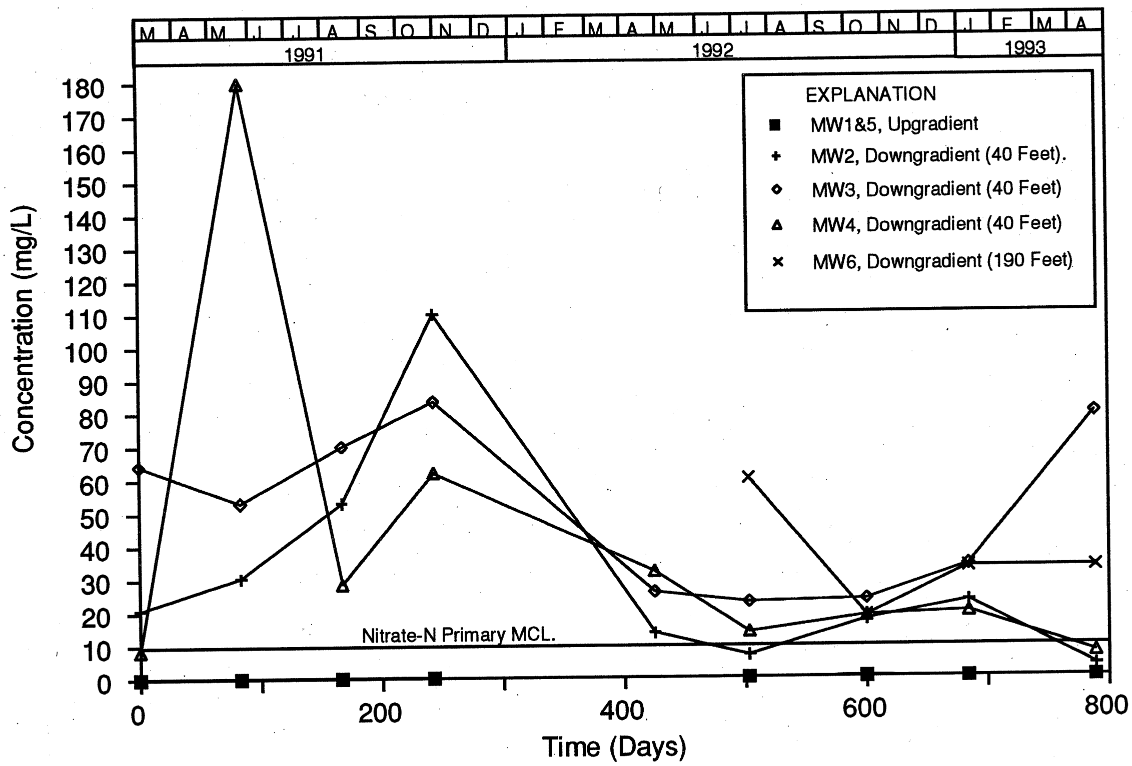

Figure 17. Whatcom Dairy #2, Ammonia-N.

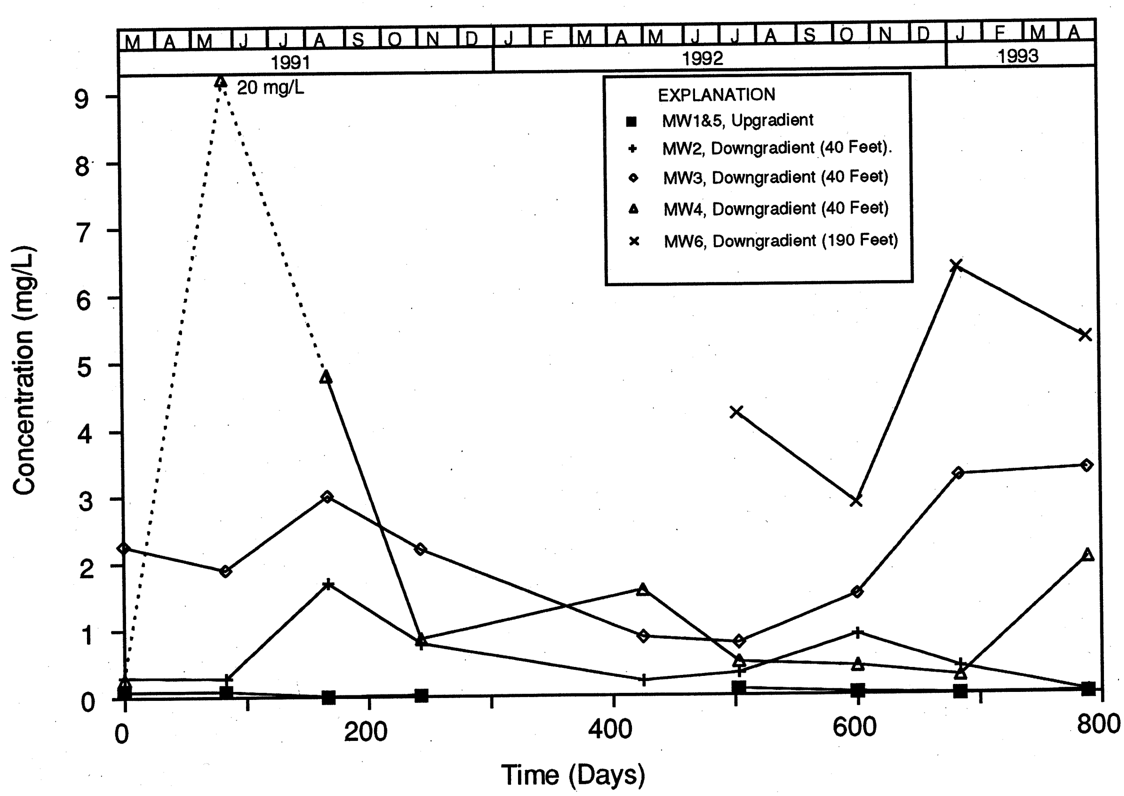

Figure 18. Total Phosphorus, Whatcom County Lagoon #2

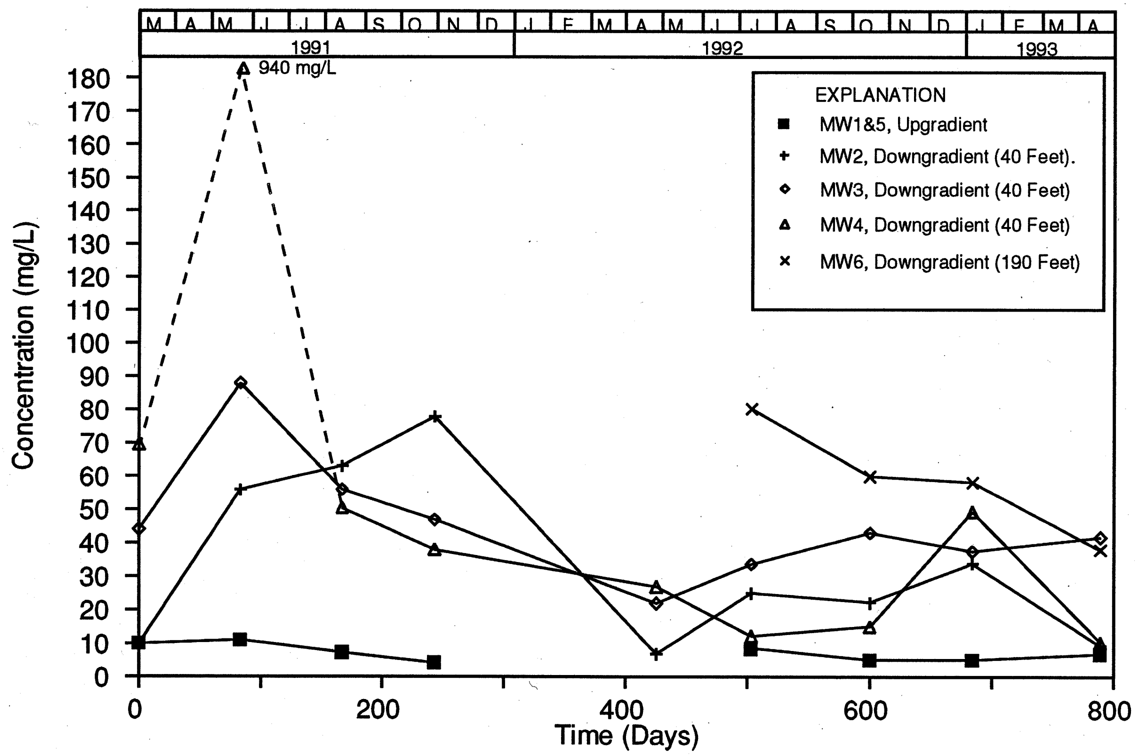

Figure 19. Whatcom Dairy #2, Chemical Oxygen Demand (COD).

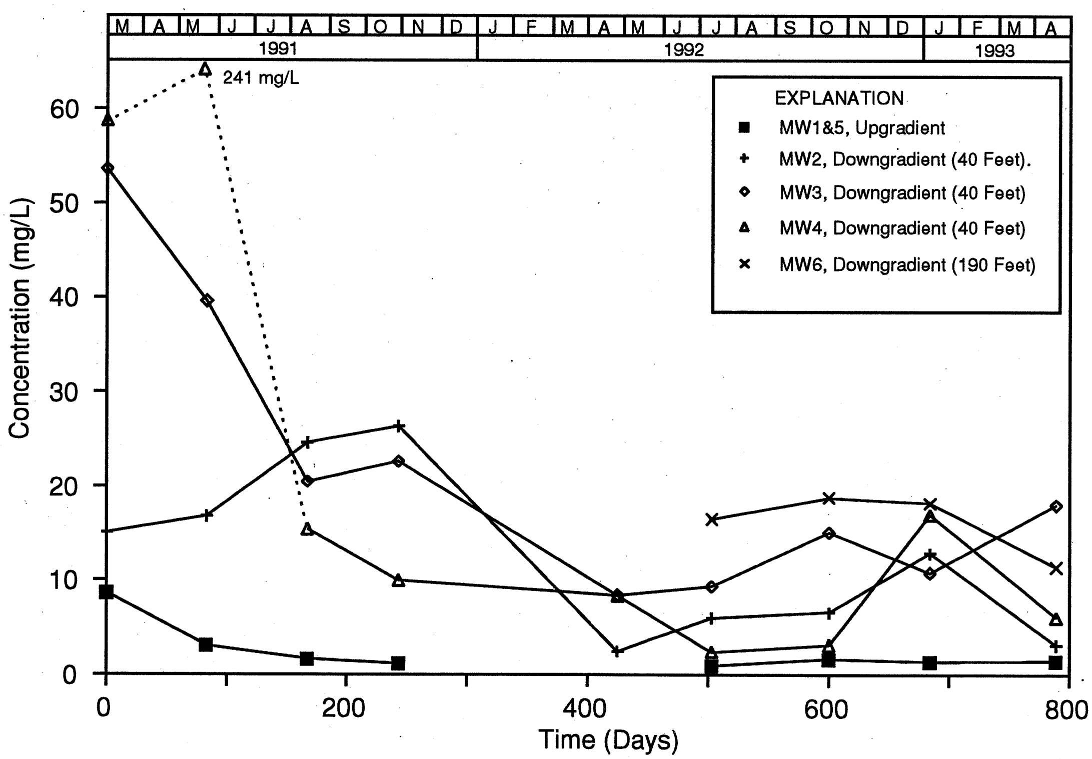

Figure 20. Whatcom Dairy #2, Total Organic Carbon (TOC).

concentrations were typically less than 2 mg/L. TOC concentrations in downgradient wells ranged between 2 and 20 mg/L.

COD and TOC concentrations at MW6, located 190 feet downgradient of the pond, were higher than concentrations in wells located near the pond the last year of monitoring. The maximum concentrations of COD (940 mg/L) and TOC (241 mg/) were observed at MW4 in May 1991.

Coliform Bacteria

Total coliform and fecal coliform bacteria, which were present in high concentrations in the wastewater (310,000 to 10,000,000 and 80,000 to 9,200,000 CFU/100ml, respectively) were only occasionally observed in ground water samples. Total coliform bacteria were detected upgradient of the pond in about half of the samples at a concentration of one CFU/100ml. Maximum densities of total coliform (2,000 CFU/100ml) and fecal coliform (180 CFU/100ml) bacteria were observed at MW4 in May 1991. Total and fecal coliform bacteria were also detected at MW3 in February 1991 at concentrations of 14 and 6 organisms/100 ml, respectively.

Summary of Whatcom Dairy #2

Leakage from the Whatcom Dairy #2 pond affected ground water quality downgradient of the pond. Concentrations of chloride, TDS, ammonia-N, total phosphorus, COD, and TOC were higher in downgradient wells than in upgradient wells.

Erickson (1992b) concluded that the water quality variations observed during the first year of monitoring at MW2 and MW4 were related to changes in ground water flow direction. High concentrations in MW2 occurred when the ground water flow direction was toward the southwest (from the lagoon toward MW2); high concentrations occurred in MW4 when ground water flow was toward the southeast (from the lagoon toward MW4). Also, the maximum concentrations observed for all parameters at MW4 in May 1991 suggested localized leakage from the lagoon. The cause of the localized leakage was not identified. After the first year of monitoring the ground water flow direction did not vary substantially and the water quality results were less variable.

The high concentrations of total phosphorus, COD, and TOC in MW6 (190 feet downgradient of MW3) the last year of monitoring were probably the result of pond leakage from the previous year or possibly from land application of wastewater to the area between MW3 and MW6.

Separation distance may be an important factor that accounts for the observed contaminant loading to ground water. Separation distance between the pond bottom and the water table was less than two feet. Occasionally, because of seasonal fluctuation, the water table contacted the pond bottom.

HORNBY DAIRY

The waste storage pond system at Hornby Dairy was designed to handle manure and wastewater for about 1200 dairy cows. The two-stage pond system consisted of two primary settling ponds (0.44 million gallons each) and a main pond (five million gallons). The ponds began operating around January 1990.

The ponds were constructed over alluvial and floodplain deposits (Campbell, 1977). The relationship of the ponds and the hydrogeology is shown in Figure 21. A driller's log for a domestic well about 200 feet south of the pond showed 87 feet of unconsolidated material: 35 feet of sandy soil, 15 feet of clay (no water), 25 feet of water-bearing clay and sand, and 12 feet of water-bearing sand and gravel. The 15 feet of clay from 35 to 50 feet probably served as a partial hydraulic barrier to vertical downward flow. The depth to water ranged from about five to ten feet. Ground water moved generally westward toward an open irrigation ditch about 1000 feet from the ponds. Hydraulic gradients ranged from 0.008 to 0.009 (foot/foot). Erickson (1992a) estimated ambient ground water flow velocity ranged from 0.3 to 29 feet per year using Darcy's Law and slug test results. He estimated ground water velocities adjacent to the pond ranged from 50 to 135 feet per year using chloride travel times.

The monitoring network (Figure 22) consisted of five monitoring wells, three private water-supply wells, a staff gage in the open irrigation ditch, and a manhole for a buried irrigation drain. Monitoring well depths ranged from 13 to 14 feet.

Water Levels

Water levels fluctuated about two feet seasonally (Figure 23). Pond fluid levels ranged from five to ten feet higher than the water table. Therefore, throughout the study period there was a potential for leakage to ground water. The separation distance, the distance between the bottom of the pond and the water table, was never less than two feet over the study period.

Water Quality

The water quality results for the Hornby Pond study are shown in Appendix F, Table F-5. The results for specific parameters are discussed below. Findings are summarized in section "Summary of Hornby Dairy" following the discussion of specific parameters.

Chloride

Chloride concentrations in the wastewater ranged from 60 to 151 mg/L. Chloride concentrations in wells are graphed in Figure 24. Upgradient concentrations (MW1) were about 10 mg/L. Downgradient of the main pond concentrations steadily increased over the study period. Final chloride concentrations for the three wells downgradient of the main pond ranged from 100 to 110 mg/L.

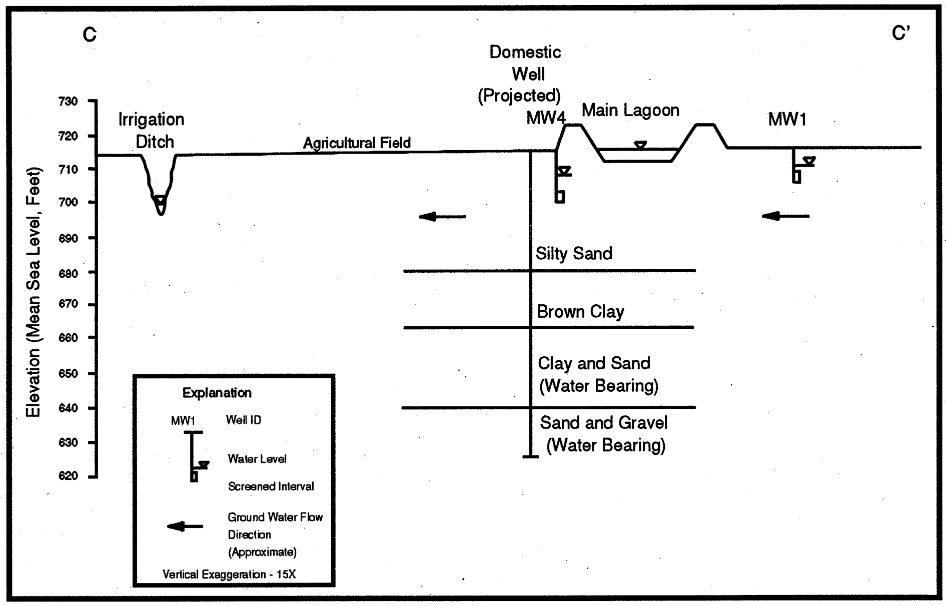

Figure 21. Hornby Dairy Hydrogeologic Profile.

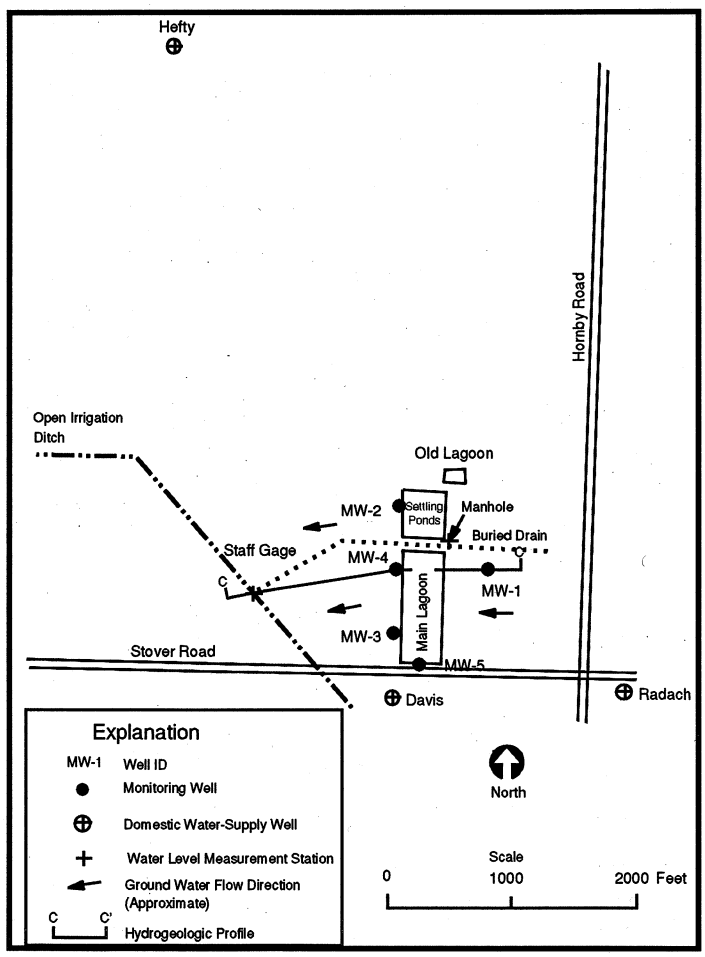

Figure 22. Hornby Dairy and Well Location Map.

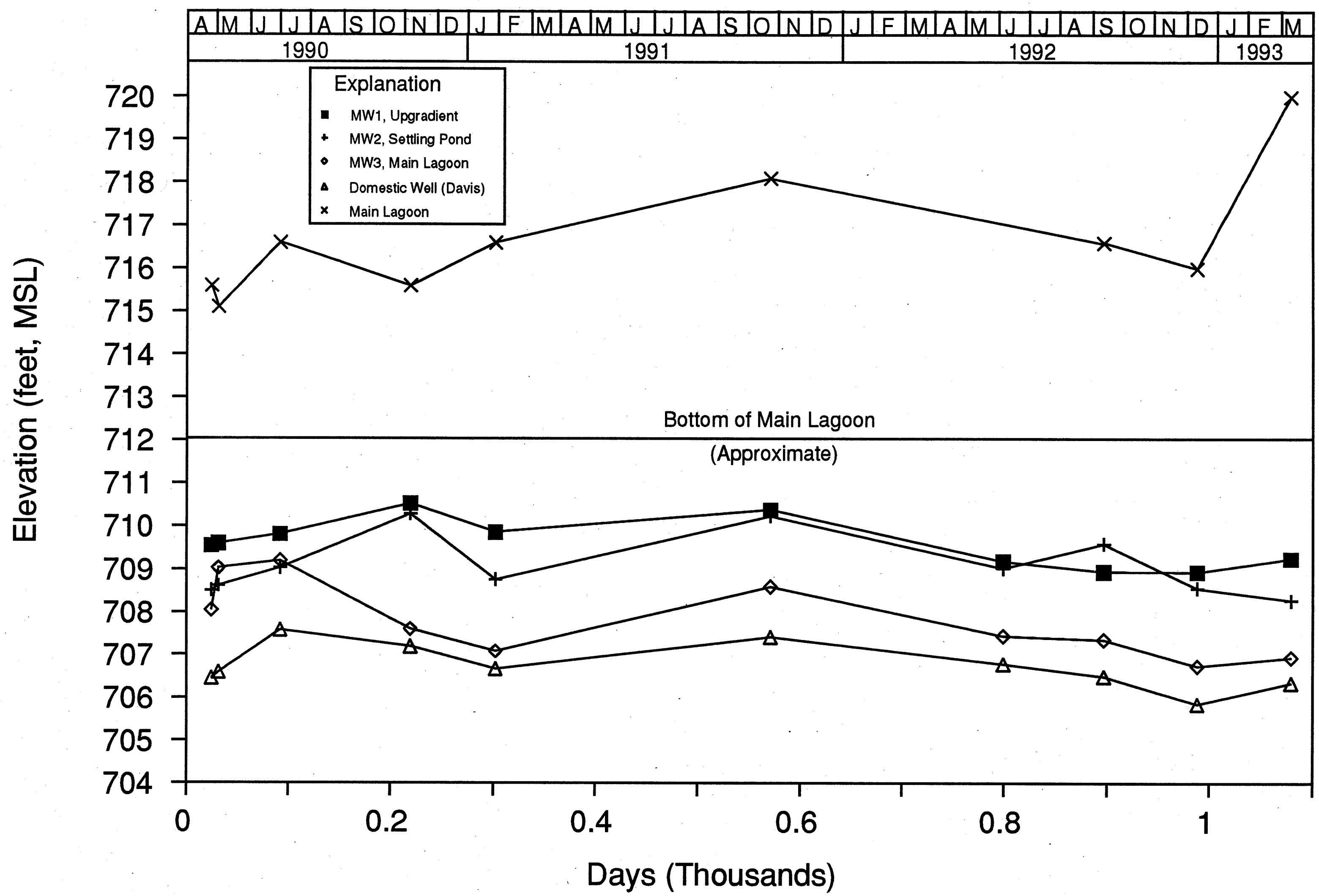

Figure 23. Hornby Dairy, Well Hydrographs and Lagoon Levels.

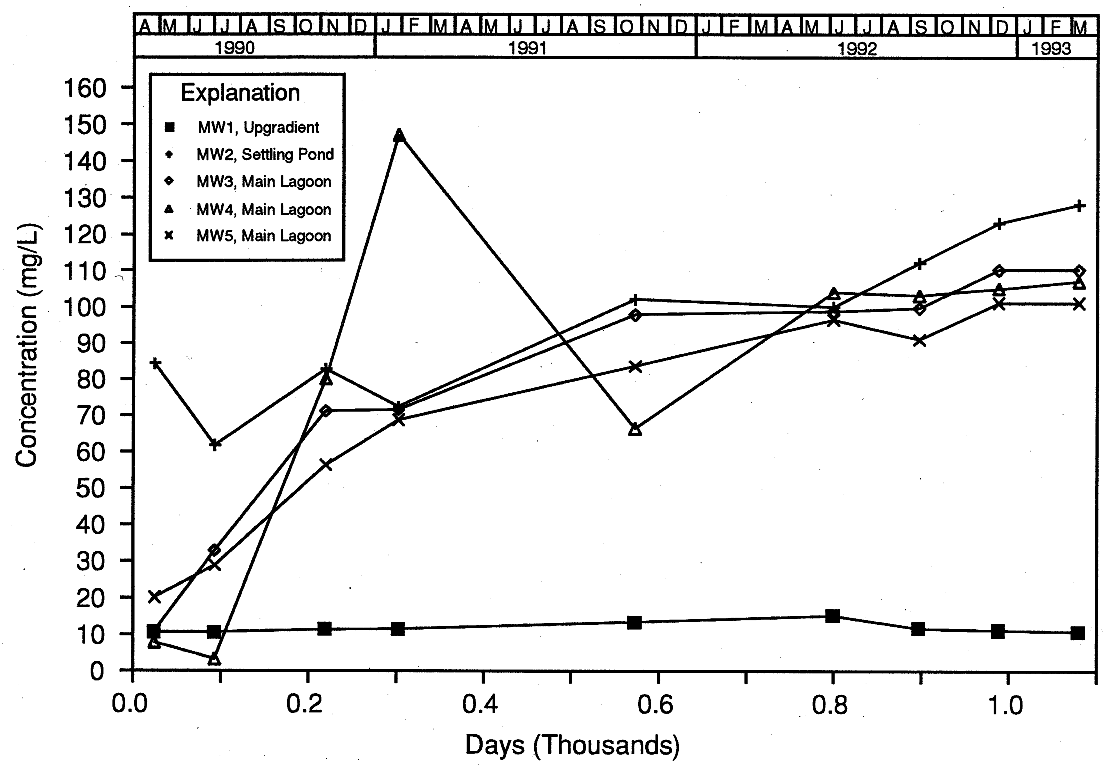

Figure 24. Hornby Dairy, Chloride.

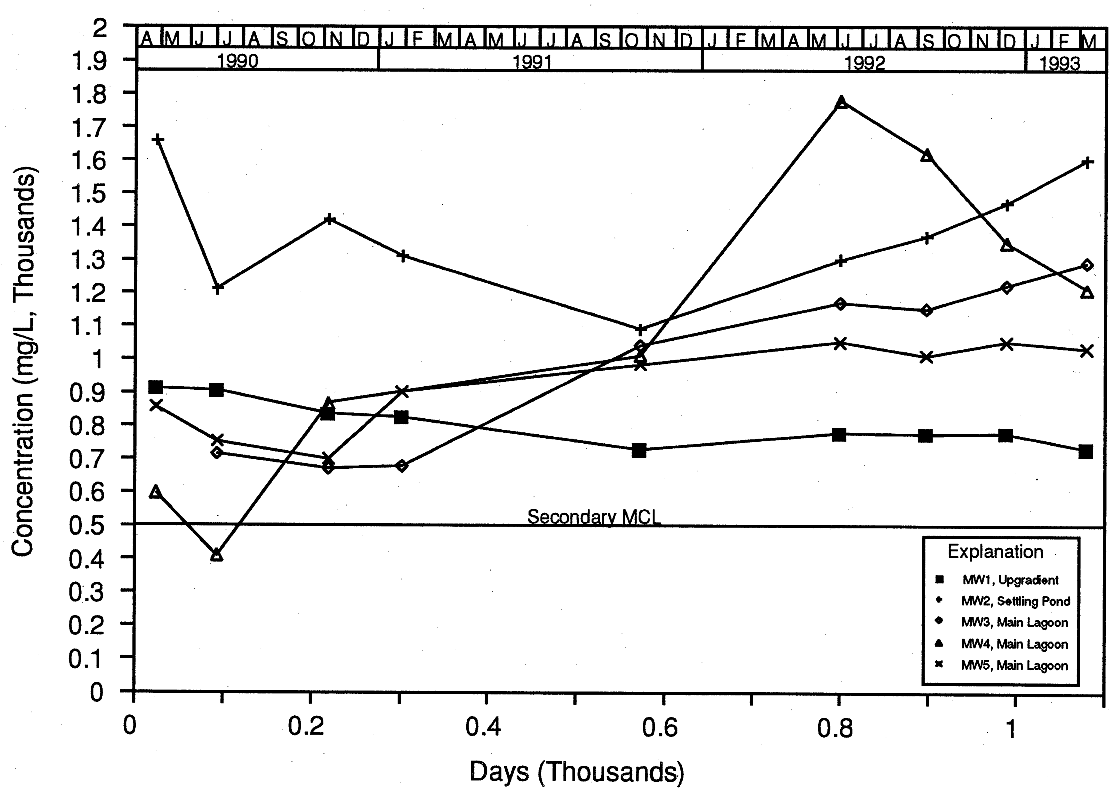

Figure 25. Hornby Dairy, Total Dissolved Solids (TDS).

Downgradient of the settling pond, at the onset of monitoring, the chloride concentration was 84 mg/L. Over the study period the chloride concentration increased steadily to 128 mg/L.

Total Dissolved Solids (TDS)

TDS concentrations in the wastewater ranged from 1160 mg/L to 1990 mg/L. TDS concentrations in wells are graphed in Figure 25. Upgradient concentrations ranged from 700 to 900 mg/L over the study period. At MW3 and MW5, TDS increased steadily (715 mg/L to 1290 mg/L at MW3; 860 mg/L to 1030 at MW5) over the study period. At MW4 the concentration increased to a maximum value (1780 mg/L) and then decreased to 1210 mg/L at the end of the study period.

Downgradient of the settling pond, at the onset of monitoring, the TDS concentration was 1660 mg/L. TDS decreased in MW2 to 1090 mg/L in October 1991 and steadily increased to 1600 mg/L by the end of the study period.

Nitrogen

Nitrogen concentrations in the wastewater, primarily as ammonia, ranged from 19 to 153 mg-N/L. Ammonia-N and nitrate+nitrite-N concentrations in wells are shown in Figures 26 and 27. Upgradient concentrations of ammonia-N typically ranged from 0.02 to 0.2 mg/L. Ammonia-N concentrations downgradient of the main pond were variable. One well, MW4, typically was higher than upgradient concentrations ranging from 0.2 to 1.0 mg/L. Concentrations at MW3 were occasionally slightly above upgradient concentrations. And at MW5 concentrations were usually less than upgradient concentrations.

Downgradient of the settling pond, ammonia-N concentrations were elevated at the onset of monitoring at 1.2 mg/L. Concentrations peaked at about 3.5 mg/L in July 1990, decreased rapidly to about 0.4 mg/L by January 1991, and then gradually decreased to about 0.1 mg/L by the end of the study period.

Upgradient concentrations of nitrate+nitrite-N (MW1) ranged from 5.8 to 10.4 mg/L over the study period. Downgradient of the main pond nitrate+nitrite-N concentrations for two of the wells, MW3 and MW5, were less than upgradient concentrations. However, the nitrate+nitrite-N concentration in well MW4 showed substantial variation ranging from less than 10 mg/L up to 84 mg/L. The maximum concentrations occurred as two distinct peaks in November 1990 (82 mg/L) and June 1992 (84 mg/L).

Downgradient of the settling pond nitrate+nitrite-N concentrations decreased from 96 mg/L at the onset of monitoring to 0.04 mg/L by the end of the study period.

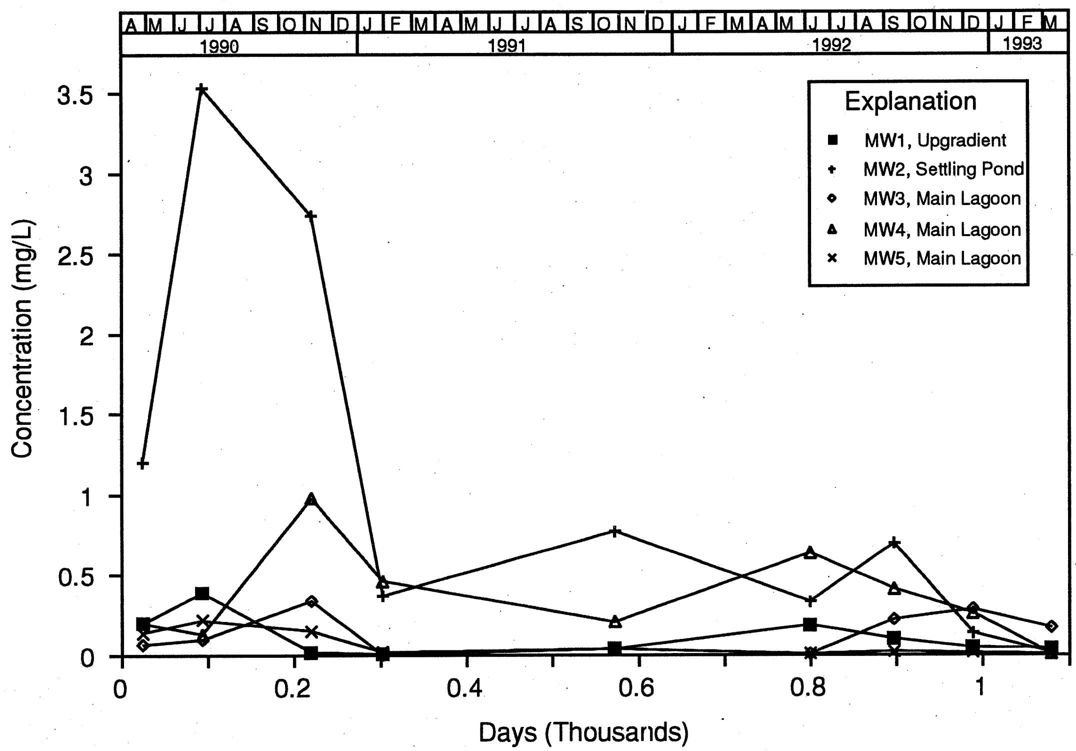

Figure 26. Hornby Dairy, Ammonia-N.

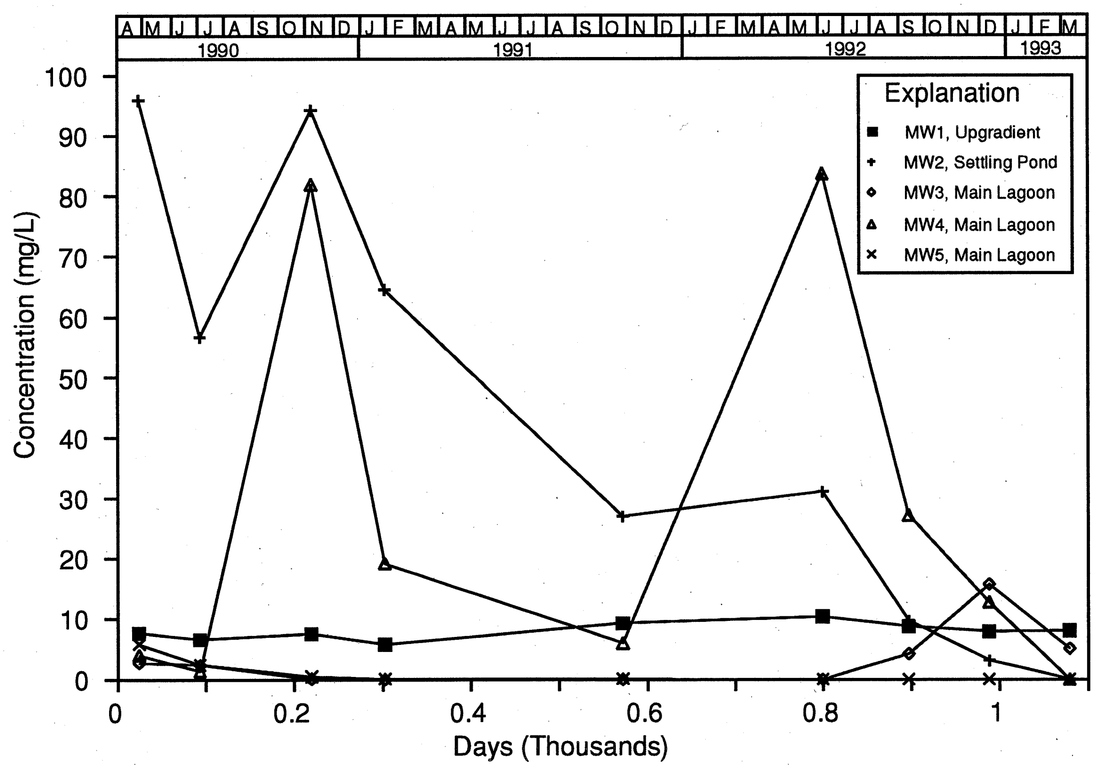

Figure 27. Hornby Dairy, Nitrate+Nitrite-N.

Total Phosphorus

Total phosphorus concentrations in the wastewater ranged from about 7 to 45 mg/L. Total phosphorus concentrations in wells are shown in Figure 28. Upgradient concentrations ranged from 0.01 to 0.15 mg/L. Downgradient of the main pond, concentrations were nearly always less than upgradient. One exception occurred at MW5 where a concentration of 1.9 mg/L was observed in November 1990.

Downgradient of the settling pond, total phosphorus concentrations increased to a peak concentration of 1.7 mg/L in January 1991 and decreased to 0.06 mg/L at the end of the monitoring period.

Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC)

COD and TOC concentrations in wastewater ranged from 26 to 2810 mg/L and 138 to 803 mg/L, respectively. COD and TOC concentrations in wells are graphed in Figures 29 and 30.

Upgradient COD concentrations were generally less than 20 mg/L and TOC concentrations were typically less than 10 mg/L.

Downgradient of the main pond, during the first year of the study COD and TOC varied substantially but, in general, upgradient and downgradient concentrations were similar. Over the remainder of the study, January 1991 to March 1993, downgradient concentrations were nearly always higher than upgradient concentrations.

Downgradient of the settling pond organic content was high (102 mg/L COD and 37 mg/L TOC) at the onset of monitoring. Concentrations decreased by January 1991 (15 mg/L, COD and 14 mg/L, TOC) and then steadily increased for the remainder of the study period.

Summary of Hornby Dairy

Pond leakage and on-site waste handling activities affected ground water quality downgradient of the Hornby Dairy main pond. Chloride and TDS concentrations in wells increased downgradient after the main pond received wastewater and were still increasing after three years. Downgradient COD and TOC concentrations were higher than upgradient concentrations but concentrations may have stabilized by the end of the study period.

Pond leakage caused increased concentrations observed at MW5, downgradient of the main pond. This well was unaffected by any other waste handling activities at the site. Results from MW5 show elevated concentrations of chloride, TDS, COD and TOC relative to upgradient concentrations.

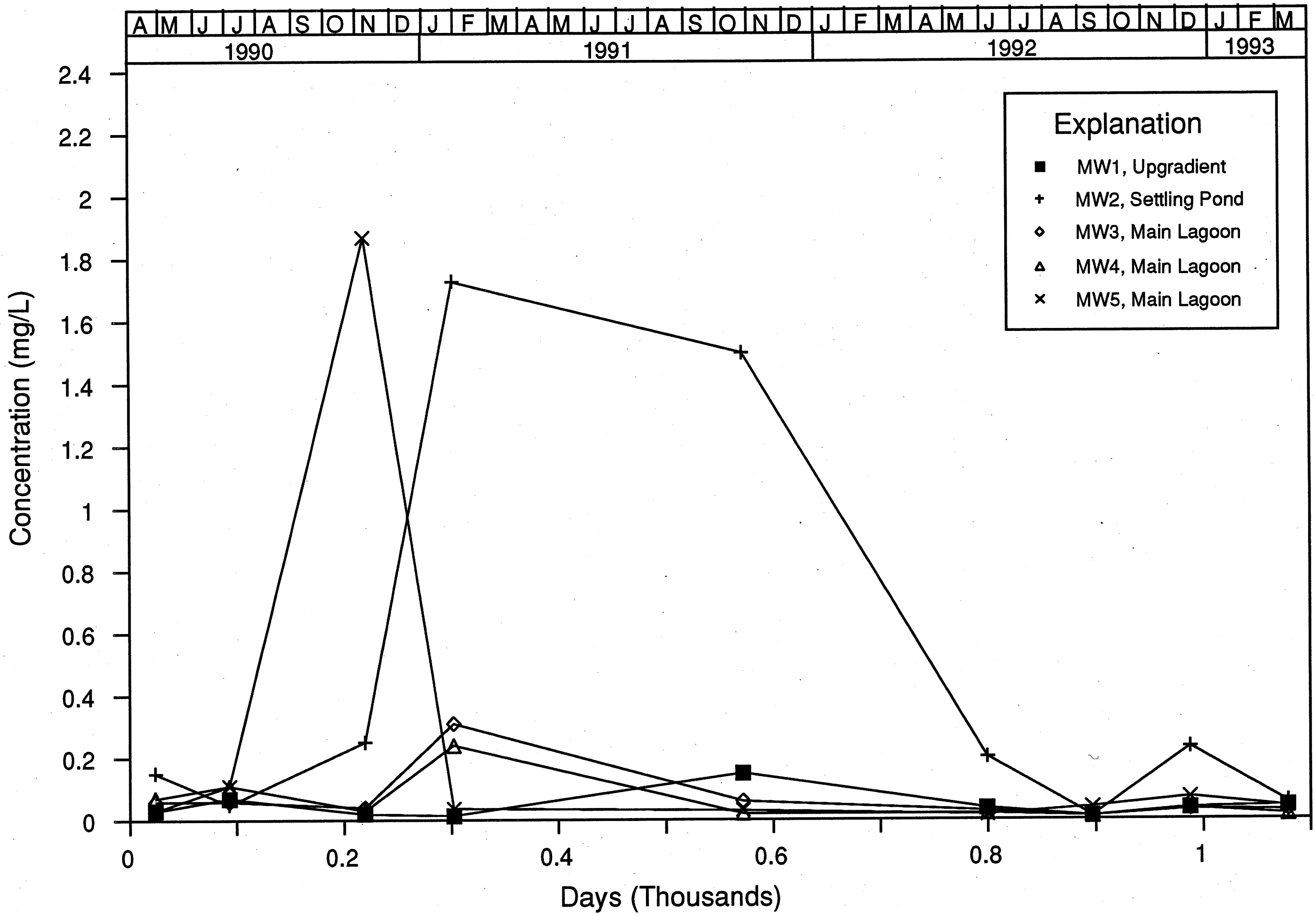

Figure 28. Hornby Dairy, Total Phosphorus.

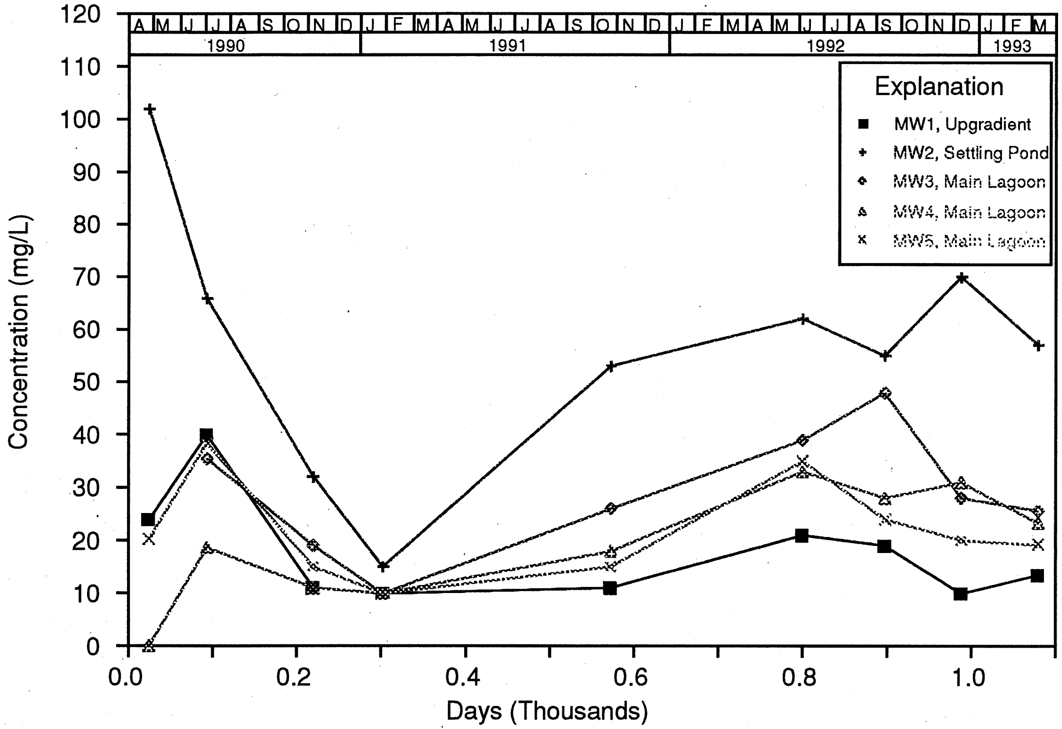

Figure 29. Hornby Dairy, Chemical Oxygen Demand (COD).

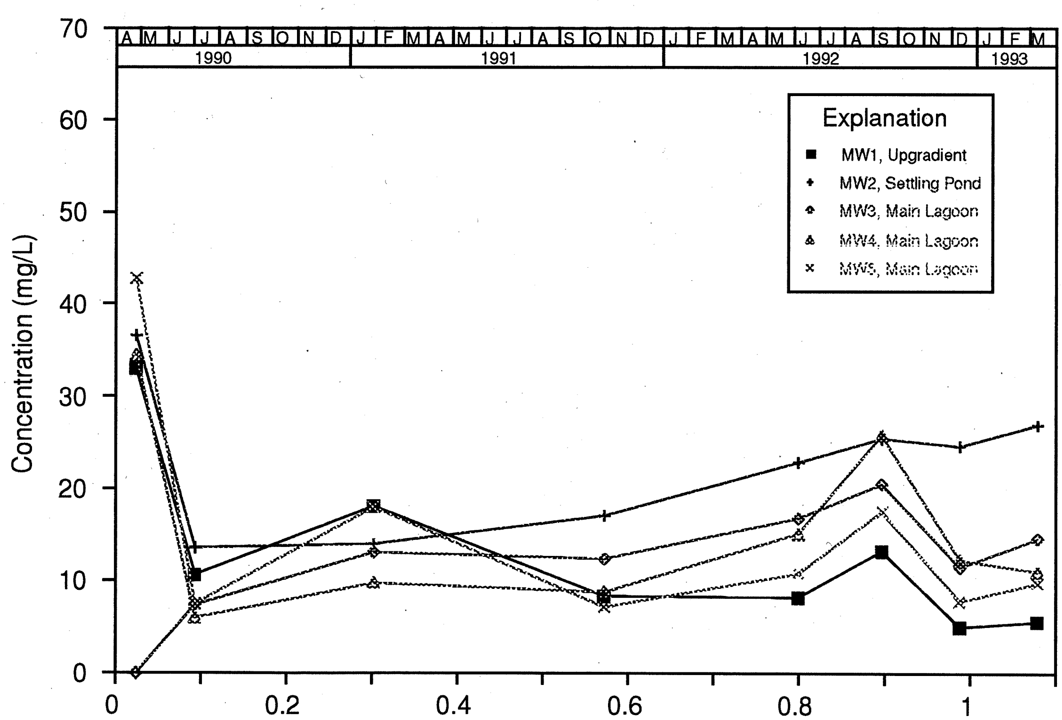

Figure 30. Hornby Dairy, Total Organic Carbon (TOC).

The combined effects of pond leakage and other waste handling activities caused the increased concentrations at MW3 and MW4. Both wells were located adjacent to a field where dairy wastewater was applied. Also, according to the dairy waste inspector, the dairy opened a discharge pipe and directly discharged wastewater to ground at the toe of the main pond embankment near MW-4. This may have been the source of the nitrate+nitrite-N spikes observed at MW4.

Four sources potentially affected the results downgradient of the settling pond (MW2): pre-existing contamination, leakage from the settling ponds, land application of wastewater to the nearby field, and manure and wastewater released next to MW2. At the onset of the monitoring, total dissolved solids (TDS), chemical oxygen demand (COD), ammonia-N, nitrate+nitrite-N, total phosphorus, and chloride concentrations were higher than upgradient concentrations. Erickson (1992a) identified two potential sources for this pre-existing contamination: the old pond that was replaced by the new pond system and wastewater discharges to ground near MW2.

The results at Hornby Dairy should not be used for evaluating the development of seals in ponds. A longer monitoring period is needed. Because of the slow ground water velocity, a long lag time existed between contaminant loading due to leakage and observed concentration changes in downgradient monitoring wells. The lag time, estimated by dividing the length of the pond perpendicular to the direction of flow by the range of the estimated ground water flow velocity, was seven years or greater (up to tens of years). The wide range is due to the uncertainty of the ground water flow velocity. As a result of the lag time, increasing chloride and TDS concentrations in wells at the end of three years did not necessarily mean that leakage rates also were increasing. It is likely that the observed chloride and TDS concentrations at the end of the study period were the result of the initial leakage when the ponds first received wastewater. To observe the effects of leakage rate changes due to seal development in the wells, would require long term monitoring on the order of seven years or greater.

SHERIDAN DAIRY

Sheridan Dairy's single-stage pond, constructed in 1985, had a capacity of 1.1 million gallons. The unlined pond was excavated about seven feet below ground surface. All manure and wastewater from the dairy was stored in the pond as there was no solids separation.

The pond, situated on the Chehalis River floodplain, was underlain by alluvial deposits consisting of mixtures of gravel, sand, silt and clay (Weigle and Foxworthy, 1962). The relationship of the pond to the site hydrogeology is shown in Figure 31. The uppermost aquifer consisted of a four-foot thick gravel layer at a depth of about 30 feet. The gravel layer appeared to continuously underlie the site. The aquifer was overlain by about 25 feet of silt and clay deposits. The silt and clay deposits acted as a confining or semi-confining unit that reduced the hydraulic connection between the pond and the aquifer. Erickson (1992c) estimated that the horizontal ground water flow velocity in the aquifer was about 1 to 2 feet per day.

The monitoring network consisted of four monitoring wells (Figure 32): one upgradient well (MW4) and three downgradient wells (MW1, MW2 and MW3). Well depths ranged from 27.6 to 32.8 feet.

Water Levels

Water elevations in monitoring wells fluctuated three to four feet over the study period (Figure 33). The fluid elevation in the pond was higher than water levels in downgradient wells between July and March. Thus, there was a potential for leakage from the pond to ground water about nine months of the year. However, the vertical downward potential is low (1foot/24 feet = 0.04). Potentiometric contour maps constructed from monitoring well water levels showed no evidence of mounding in the target aquifer due to leakage from the lagoon (Erickson, 1992c).

Water Quality

Results of water chemistry and bacteriological analyses are shown in Appendix F, Tables F-6 and F-7, respectively. The results for specific parameters are discussed below. Findings are summarized in section "Summary of Sheridan Dairy" following the discussion of specific parameters.

<u>Chloride</u>

Chloride concentrations in wastewater ranged from 158 to 463 mg/L. Chloride concentrations in wells are graphed in Figure 34. Upgradient concentrations ranged from 38 to 44 mg/L. Concentrations in two downgradient wells (MW1 and MW3) were substantially

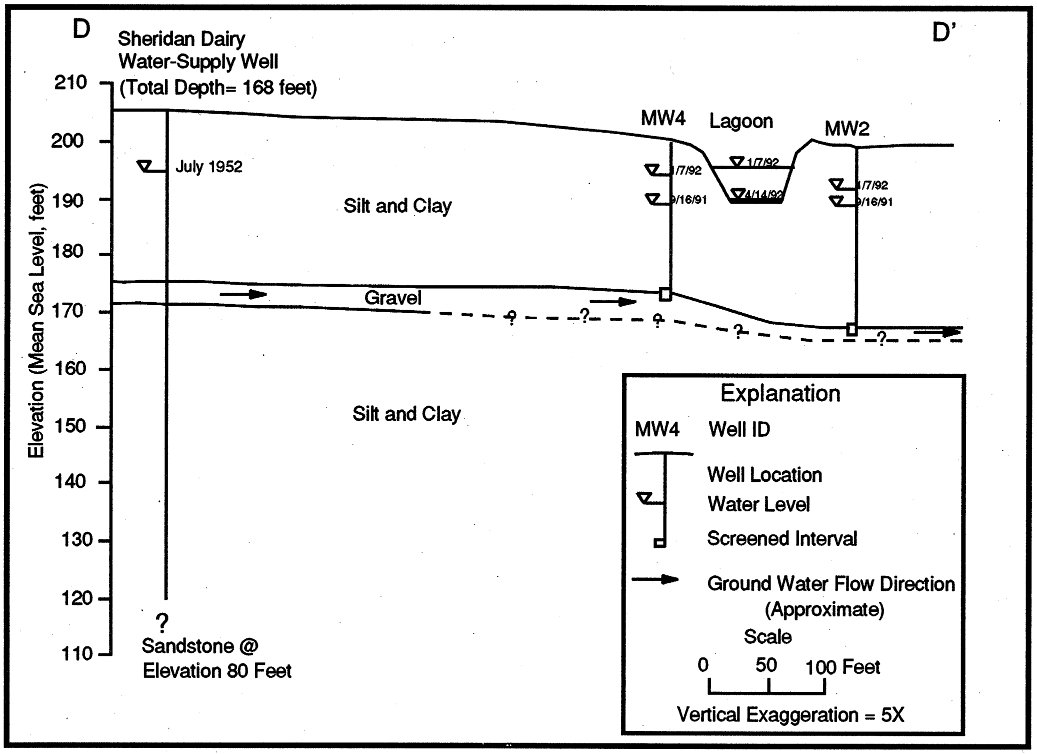

Figure 31. Sheridan Dairy, Hydrogeologic Profile.

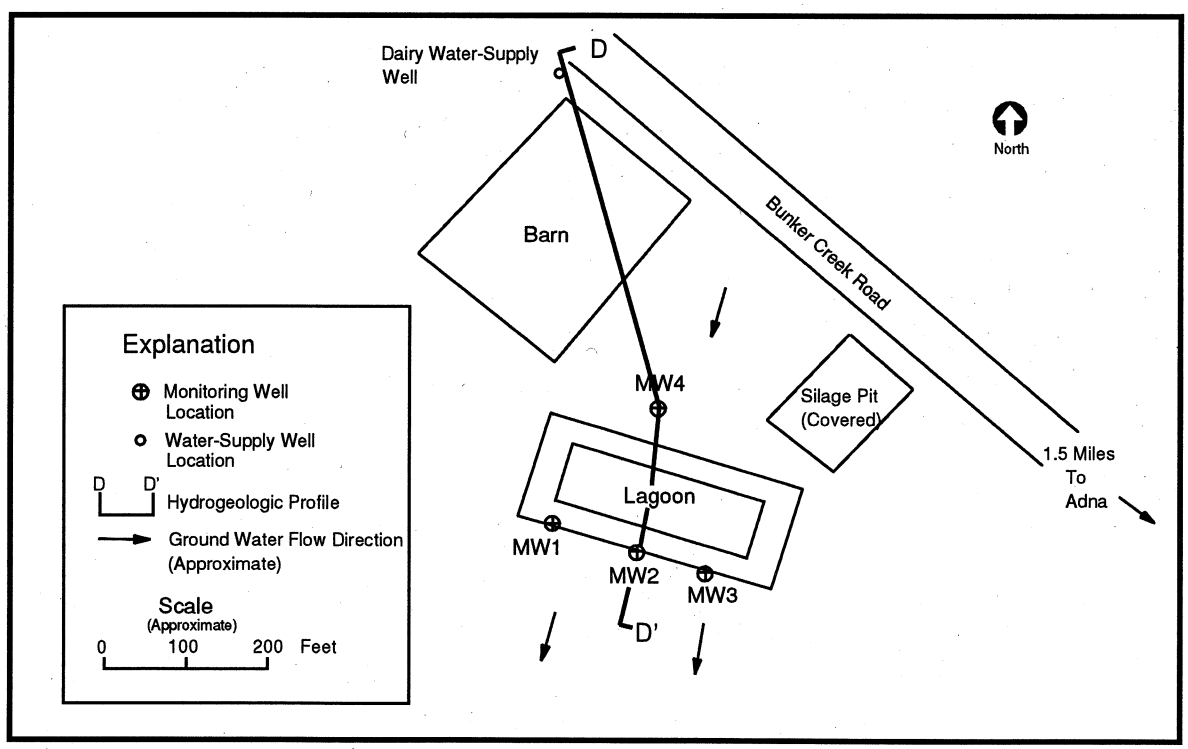

Figure 32. Sheridan Dairy, Well Location Map.

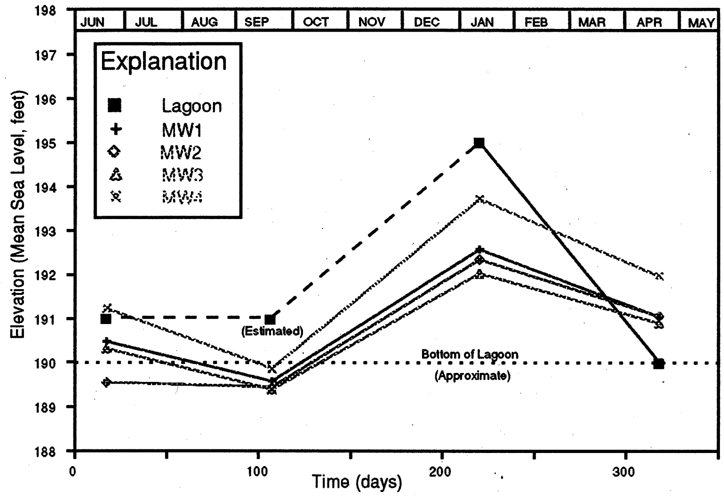

Figure 33. Sheridan Dairy, Hydrographs for Wells and Lagoon,

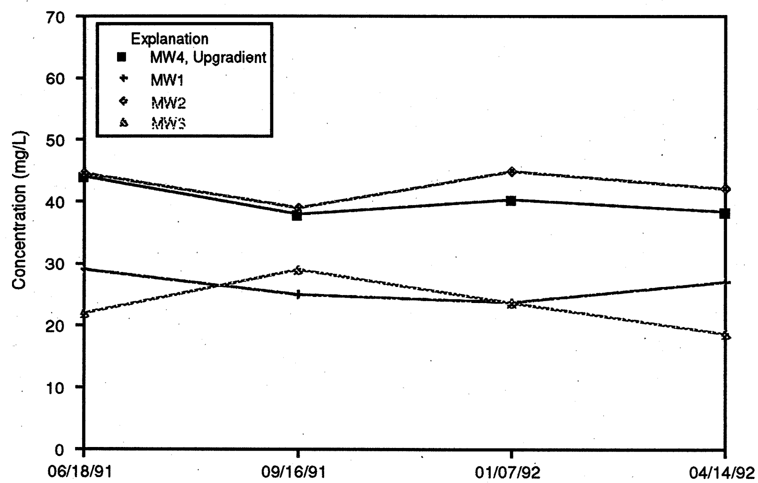

Figure 34. Sheridan Dairy, Chloride.

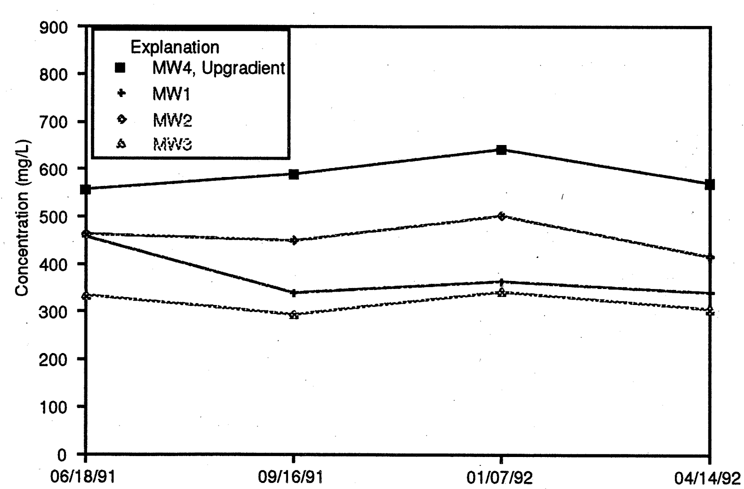

Figure 35. Sheridan Dairy, Total Dissolved Solids (TDS).

less than upgradient concentrations. Concentrations in one downgradient well (MW2) were essentially the same as upgradient.

Total Dissolved Solids (TDS)

TDS concentrations in wastewater ranged from 5800 to 9180 mg/L. TDS concentrations in wells are graphed in Figure 35. Upgradient concentrations ranged from 557 to 643 mg/L. Downgradient concentrations were substantially less ranging from 295 to 502 mg/L.

Nitrogen

The most abundant nitrogen species present in the wastewater was ammonia-N with concentrations ranging from 230 to 594 mg/L. Upgradient ammonia-N concentrations ranged from 0.5 to 0.7 mg/L. Downgradient concentrations were typically less than 0.1 mg/L.

Nitrate+nitrite-N was not detected in the upgradient well but was present in two downgradient wells (MW2 and MW3) at concentrations ranging from 1.6 to 4.7 mg/L.

Total Phosphorus

Total phosphorus concentrations in wastewater ranged from 125 to 140 mg/L. Both upgradient and downgradient concentrations in wells were essentially the same ranging from 0.1 to 0.5 mg/L.

Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC)

COD and TOC concentrations in wastewater ranged from 2100 to 10,800 mg/L and 724 to 1990 mg/L, respectively. Upgradient COD concentrations ranged from 11 to 40 mg/L and TOC concentrations ranged from 5.5 to 6.4 mg/L. Downgradient concentrations for COD (2.3 to 11 mg/L) and TOC (less than 1 to 3.8 mg/L) were less than upgradient concentrations.

Coliform Bacteria

Total and fecal coliform bacteria concentrations in waste water ranged from 150,000 to 800,000 and 120,000 to 520,000 CFU/100ml, respectively. Total coliform bacteria were detected in only one sample (June 1991) and that was in the upgradient well. Fecal coliform bacteria were not detected in any of the samples.

Summary of Sheridan Dairy

Based on one year of monitoring Erickson(1992c) concluded that pond leakage was not affecting ground water quality. Concentrations of TDS, COD, TOC, and ammonia-N were higher in the upgradient monitoring well than in downgradient wells. One exception was nitrate+nitrite-N. Nitrate+nitrite-N was higher in two downgradient wells relative to upgradient concentrations. However, because no other parameters tested were greater than upgradient concentrations, it was unlikely that leakage from the pond caused the elevated nitrate+nitrite-N.

The ground water quality in the upgradient well (MW4) was poor. Concentrations of COD, TDS, ammonia-N, and chloride were higher than expected for the East Chehalis alluvial aquifer (Erickson, 1993). It seems unlikely that this degradation is due to leakage from the pond because there is no evidence of mounding in the target aquifer and contaminant travel time through the clayey silt layer is estimated to be tens of years. Also, no other onsite sources exist directly upgradient of MW4. Most likely, the degradation is from offsite sources related to land uses (agricultural fields or septic systems for private residences) upgradient of MW4.

DISCUSSION

Design and Construction

The Soil Conservation Service (SCS) provides technical guidelines for the construction, maintenance, and operation of dairy waste storage ponds (SCS 1979, 1987, and 1994). Table 1 summarizes the design and construction of the studied ponds. It is not known to what extent these ponds meet existing guidelines. The pond system at Whatcom Dairy #1 was designed and constructed without SCS assistance. SCS assisted in the original design and construction of Whatcom Dairy #2 in 1980 but was not involved with the widening and renovation in 1989. The ponds at Hornby Dairy and Sheridan Dairy were designed by SCS, however, the construction was not overseen.

Water Quality Standards

The observed concentrations can be put into perspective when discussed relative to drinking water and ground water quality standards.

Drinking water standards and ground water quality standards for the parameters tested are listed in Table 2. With the exception of specific conductance, for which there is no ground water standard, the drinking water standards and the numeric criteria of the ground water quality standards are identical. Two parameters, nitrate-N (10 mg/L) and total coliforms (one Colony Forming Unit (CFU)/100mL) have Primary Maximum Contaminant Levels (MCLs). Primary MCLs are maximum allowable concentrations for public water-supply systems based on potential adverse health effects (Department of Health, 1992). Three parameters: specific conductance (700 micromhos/cm @ 25°C), TDS (500 mg/L), and chloride (250 mg/L) have Secondary MCLs. Secondary MCLs are based on aesthetics such as taste, odor, or discoloration.

In addition to the numeric criteria, the ground water standards have narrative antidegradation and nondegradation standards. However, guidance for the implementation of the narrative standards has not been finalized. Compliance with the narrative standards is not discussed here.

Nitrate

Nitrogen was present in the wastewater and ground water primarily as ammonia-N for which there is no drinking water or ground water quality standard. However, some of the ammonia-N will eventually nitrify to nitrite and nitrate. Whatcom Dairy #1 and Whatcom Dairy #2 pond systems were substantial sources of ammonia-N. Peak concentrations up to 180 mg/L were observed downgradient of the ponds and were usually between 30 to 60 mg/L. Although not all of this ammonia-N would be converted to nitrate, downgradient concentrations of nitrate-N may exceed 10 mg/L. Barring other sources of nitrogen, nitrate-N concentrations downgradient of the pond should remain less than observed ammonia-N

Table 1. Summary of Waste Storage Pond Design and Construction

Name	Capacity (million gallons)	Liner Type	Date First Used	Date Monitoring Began	Aquifer Material	Depth to Water Table (BGS[1], feet)	Separation Distance[3] (feet)	Leakage Detected	Remarks:
Whatcom Dairy #1 Settling Pond	2.4	Compacted	3/90	2/90	Sand and	3 to 5	-5 to +3	Yes	Designed and constructed
Main Lagoon	10.4	Topsoil	5/90		gravel		-2 to +6	Yes	without SCS assistance.
Whatcom Dairy #2	2.5	Unlined	1980 (widened 1989)	2/91	Sand and gravel	5 to 9	-1.5 to +2	Yes	Originally designed with SCS assistance. Lagoon was widened without SCS assistance.
Hornby Dairy (Yakima County)									
Settling Ponds	0.8	Unknown	1/90	4/90	Silty sand	5 to 10	+2 to +4	Yes	Designed by SCS but construction was not overseen.
Main Lagoon	5.0	Unknown	1/90				+3 to +5		
Sheridan Dairy (Lewis County	1.1	Unlined	1985	6/91	Gravel	5 to 10[2]	+25	No	Designed with SCS assistance.

[1]BGS = Below Ground Surface.
[2]The aquifer is overlain by about 25 feet of silt and clay deposits. Water levels rise to within 5 to 10 feet of the surface when wells penetrate the aquifer.
[3]Separation Distance:
1) For unconfined aquifers, the distance from the bottom of the lagoon to the water table.
2) For confined aquifers, the distance from the bottom of the lagoon to the top of the aquifer.

Table 2. Whatcom County Dairy Lagoon #2, Drinking Water Standards and Ground Water Quality Standards (mg/L unless shown otherwise).

Parameter	Primary Maximum Contaminant Level (MCL)[1]	Secondary Maximum Contaminant Level (MCL)[2]	Ground Water Quality Standards[3]
Chloride	None	250	250
Total Dissolved Solids	None	500	500
Total Organic Carbon	None	None	None
Chemical Oxygen Demand	None	None	None
Ammonia-N	None	None	None
Nitrate-N	10	None	10
Total Phosphorus	None	None	None
Specific Conductance (micromhos/cm @ 25°C)	None	700	None
Total Coliform Bacteria (Colony Forming Units/100mL)	1	None	1
Fecal Coliform Bacteria (Colony Forming Units/100mL)	None	None	Noe

None= No standard established. [shaded] = Standard established.

1 Department of Health (1992) Chapter 246-290 WAC. Primary MCLs are maximimum allowable contaminant concentrations for public water supply systems based on potential adverse health effects.

2 Department of Health (1992) Chapter 246-290 WAC. Secondary MCLs are maximum allowable contaminant concentrations for public water supply systems based on aesthetics such as taste, odor, or staining.

3 Chapter 173-200 WAC, Water Quality Standards for Ground Waters of the State of Washington.

Note: Water Quality Standards for Ground Water have narrative antidegradation and nondegredation standards to protect existing ground water quality and beneficial uses.

concentrations. Dispersion, volatilization, and adsorption will reduce ammonia-N concentrations. The nitrate-N concentrations that may occur downgradient of the ponds cannot be predicted from the existing data.

Nitrate+nitrite-N concentrations that exceeded 10 mg/L were observed. Nitrate+nitrite-N concentrations upgradient of Whatcom Dairy #1 exceeded 90 mg/L. And at Hornby Dairy upgradient nitrate+nitrite-N concentrations slightly exceeded 10 mg/L on occasion. These occurrences were not related to pond leakage but to upgradient waste application or other land use. Also at Hornby Pond, one downgradient well (MW4) had two nitrate+nitrite-N concentrations exceeding 80 mg/L. These high concentrations probably were due to waste discharges to ground near the monitoring well and not pond leakage.

Total Coliform Bacteria

Total coliform bacteria were observed intermittently in upgradient and downgradient monitoring wells. Any detection of total coliform bacteria would exceed the MCL (1 CFU/100ml). During the study period at all four ponds (about 180 samples) total coliform bacteria were detected ten times in downgradient wells and five times in upgradient wells. Generally these occurrences were between 1 and 3 CFU/100ml. Exceptions were the coliform counts of 2000 CFU/100ml and 14 CFU/100ml observed downgradient of Whatcom Dairy #2 and the 148 CFU/100ml count at Whatcom Dairy #1 (MW2).

Total Dissolved Solids

TDS exceeded the 500 mg/L MCL at Whatcom Dairy #1 in all downgradient wells at least a portion of the time (Figure 6). The maximum concentration was 1640 mg/L at MW2 in August 1990. After this peak, concentrations downgradient of the main pond decreased to slightly below 500 mg/L by the end of the study period. Downgradient of the settling pond, concentrations continuously exceeded 500 mg/L since the onset of monitoring. TDS concentrations upgradient of Whatcom Dairy #1 ponds increased during the study period. At the onset of the study TDS concentrations were less than 200 mg/L but increased to about 900 mg/L by the end of the study period. TDS concentrations exceeded 500 mg/L downgradient of Whatcom Dairy #2 pond the first year but were below 500 mg/L the remainder of the study period. At Hornby and Sheridan Dairies upgradient TDS concentrations exceeded 500 mg/L at the onset of monitoring.

Specific Conductance

Specific conductance, an indirect measure of TDS, was expected to mimic the TDS distributions. At Whatcom #1 Dairy specific conductance exceeded 700 micromhos/cm in all wells downgradient of the main pond at least a portion of the time. The maximum observed measurement was over 1500 micromhos/cm at MW2. At the end of the study specific conductance was still above 700 micromhos/cm at MW3 but was below the standard in MW1 and MW2.

Specific conductance downgradient of the settling pond at Whatcom #1 exceeded 700 micromhos/cm continuously, even at the onset of monitoring. The maximum measurement, 2000 micromhos/cm, occurred in October 1992.

At Whatcom #2 specific conductance exceeded the drinking water standard most of the time at MW3 but was below the standard in MW2 and MW4. Major excursions above the standard did occur at MW2 (1010 micromhos/cm) and MW4 (2080 micromhos/cm) in the spring and fall of 1991.

At Hornby and Sheridan Dairies upgradient and downgradient specific conductance measurements exceeded 700 micromhos/cm throughout the study.

Chloride

None of the chloride concentrations in monitoring wells exceeded the drinking water standard of 250 mg/L.

Distance Affected Downgradient

Contaminant concentrations generally decrease with distance from the leaking ponds due to a number of processes that include dispersion, adsorption, biologic and chemical degradation, and volatilization. These processes are contaminant specific and site specific. For example, chloride concentrations decrease downgradient primarily from dispersion because chloride does not degrade and does not adsorb to aquifer media. Changes in organic concentrations in ground water, measured by TOC and COD, are probably due to a combination of biological degradation and dispersion.

This study does not define the total distance affected downgradient of the ponds. However, effects were observed to a distances up to 190 feet. Two wells located about 170 feet downgradient of Whatcom Dairy #1 ponds showed substantial water quality effects. Also, a well 190 feet downgradient of the Whatcom Dairy #2 pond showed substantial effects, at least a portion of which was due to leakage. Effects were not observed at greater distances however the data are limited. One year of monitoring at MW8, 1800 feet downgradient of the Whatcom Dairy #1, did not show substantial changes of water quality. Also, Garland and Erickson (1994) saw no statistically significant changes in ground water quality in domestic wells located about 2000 feet from the pond at Whatcom Dairy #1. However, these wells were not directly downgradient of the ponds.

Erickson (1991) estimated the distance affected downgradient of the main pond at Whatcom Dairy #1 was a few hundred feet. For his estimates he used observed decreases of peak chloride concentrations in wells at varying distances from the pond. However, these estimates did not take into account long term leakage. Based on the evidence for continued leakage from the main pond and the settling pond, the distance affected downgradient of ponds may be substantially greater than a few hundred feet over the long term.

CONCLUSIONS

1. Leakage from three of the four pond systems adversely affected ground water quality. At two dairies, Whatcom Dairy #1 and Whatcom Dairy #2, concentrations of chloride, total dissolved solids, ammonia-N, chemical oxygen demand and total organic carbon in ground water were substantially higher downgradient of ponds than upgradient. At Hornby Dairy in Yakima County, concentrations of chloride, total dissolved solids, total organic carbon, and chemical oxygen demand were elevated relative to upgradient concentrations. The increased concentrations were, at least in part, the result of leakage from the three pond systems.

2. Downgradient of the main pond at Whatcom Dairy #1 concentrations increased after the pond first received wastewater, reached maximal concentrations in about three months, then decreased to levels that were above initial concentrations. This pattern suggests an initial high leakage rate after the pond first received wastewater followed by sustained at a lower leakage rate. This is consistent with the formation of a partial seal that reduces but does not eliminate pond leakage. Because of the slow ground water flow velocities at Hornby Dairy, also a new pond system, the three-year study period was too short to observe concentration changes due to sealing.

3. The proximity of the pond bottom and the water table (separation distance) may affect contaminant loading to ground water. Concentrations downgradient of the settling pond at Whatcom Dairy #1 were substantially higher than concentrations downgradient of the main pond during the last two years of the study. Over this time period the water table appeared to contact the bottom of the settling pond seasonally but not the main pond. At Whatcom Dairy #2, contaminant loading to ground water was substantial and the water table rose close to or contacted the pond bottom seasonally.

4. Chloride, total dissolved solids, total organic carbon and chemical oxygen demand were good indicators of leakage. All parameters were present in the wastewater at concentrations much greater than ambient ground water and were mobile in ground water.

5. Coliform bacteria were poor indicators of ground water contamination from pond leakage. Coliform bacteria were observed only intermittently in downgradient wells.

6. Sources of contaminant loading other than pond leakage also affected ground water quality. Sources observed or suspected were:

    a. Land application of wastewater to areas upgradient of the monitoring network (Whatcom #1 Pond).
    b. Inadvertent concentrated wastewater discharges to ground adjacent to monitoring wells (MW2 and MW4, Hornby Pond).

c. Pre-existing ground water contamination (MW6, Whatcom #1 Pond; MW2, Hornby Pond).
d. Effects of other non-facility activities upgradient of the monitoring network (possibly Whatcom #1 Pond).

7. Upgradient sources of ground water contamination were substantial. At Whatcom Dairy #1, upgradient concentrations of chloride and TDS were higher at the end of the study than the concentrations downgradient of the main pond. Land application of dairy wastes to the field upgradient of the pond contributed to the degradation.

8. Total dissolved solids and specific conductance exceeded drinking water and ground water quality standards in downgradient wells at all three ponds showing leakage. However, at one of these ponds (Hornby Dairy), upgradient concentrations also exceeded the standards. Ammonia-N concentrations consistently exceeded 10 mg/L at Whatcom Dairy #1 and Whatcom Dairy #2 and ranged as high as 180 mg/L. The potential for nitrate-N concentrations to exceed the Primary Drinking Water MCL and the Ground Water Quality Standard (10 mg/L) downgradient of these ponds exists. Intermittent occurrences of total coliform bacteria also exceeded standards.

9. Ground water monitoring for particular analytes is a viable tool for measuring the effects of pond leakage on ground water. Ground water monitoring provides measured concentrations of contaminants in ground water and, once the ground water flow system is characterized, provides a means to assess cause and effect relationships between site activities and contaminant loading. However, ground water monitoring is labor intensive and requires hydrogeologic and sampling expertise, laboratory support, and a long term commitment.

RECOMMENDATIONS

Dairy waste storage ponds that are constructed over shallow ground water are likely to adversely affect ground water quality. The extent to which leakage from ponds is a threat to human health and ground water quality statewide is unknown. The following recommendations, if initiated, would provide valuable information on the extent and severity of the problem in Washington State.

1. An inventory of ponds constructed over shallow, water-table aquifers should be conducted to assess the extent of the problem in Washington State. A four-tiered approach for this inventory is suggested:

    - Overlay commercial dairy locations from the Department of Agriculture database with surficial aquifer maps (Draft maps have been prepared for most of the state for the Pesticide Monitoring Project by Ecology's Environmental Investigation.)

    - Review SCS files, design, and construction records for dairies located over shallow aquifers and identify dairies with ponds that were constructed with little or no separation distance between the seasonal high water table and pond bottoms.

    - Conduct field screening of selected ponds using surface geophysical methods (electromagnetic (EM) or resistivity surveys) to identify whether leakage has occurred.

    - Select a subset of the EM surveyed dairies for ground water monitoring to correlate EM results with actual contaminant concentrations in ground water.

2. Additional studies are needed to determine the effect of dairy wastes on ground water. In general, because ground water can be affected by multiple activities, future studies should be comprehensive and multidisciplinary rather than focusing on a single issue. Studies should be designed to address the major aspects of dairy waste management including pond leakage, land application of wastewater and manure solids, nutrient uptake, use of inorganic fertilizer, cumulative effects of multiple farms, upgradient land uses and potential effects on water quality.

To fill data gaps the following studies are recommended:

- Conduct ground water monitoring at several SCS designed and constructed ponds to ensure that the ponds adequately protect ground water. Ponds should be located over shallow ground water with ground water velocities of about 1 foot/day or greater.

- Conduct a critical literature review of the fate and transport of nitrogen, phosphorus, and organic contaminants in ground water. Focus on quantifying fate and transport processes such as sorption, nitrification and denitrification, degradation, and volatilization. Quantification of these processes would allow reasonable estimates of the effects of lagoon leakage on ground water quality.

- Search Washington State Department of Health water quality database for elevated nitrate and chloride concentrations to identify whether public wells in dairy areas are being affected.

3. Pending the implementation of Recommendation 1 (pond inventory), SCS, in cooperation with Ecology, should develop options to modify or retrofit existing lagoons that are adversely affecting ground water. Options to be evaluated should include lagoon replacement, liner retrofits to meet current requirements, liner modifications to reduce leakage, and ground water level controls. The evaluations should consider technical feasibility, effectiveness and cost.

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APPENDICES

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APPENDIX A

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Table A–1. Dairy Lagoon Parameters, Test Methods, and Method Detection Limits.

Parameter	Method of Analysis	Reference	Detection Limit
Water Level	Electric Well Probe	NA	0.01 feet
pH	Beckman pH Meter	NA	0.1 Std Units
Specific Conductance	YSI Conductance Meter	NA	10 umhos/cm
Temperature	Beckman Temperature Probe	NA	0.1 C
Ammonia–N	EPA Method 350.1	EPA (1983)	0.01 mg/L
Nitrate+Nitrite–N	EPA Method 353.2	EPA (1983)	0.01 mg/L
Total Phosphorus	EPA Method 365.1	EPA (1983)	0.01 mg/L
Total Persulfate Nitrogen	EPA Method 353.2	EPA (1983)	0.1 mg/L
Chloride	Std Methods No. 429	APHA (1985)	0.1 mg/L
Total Dissolved Solids	Std Method No. 209B	APHA (1985)	10 mg/L
Total Suspended Solids	Std Method No. 205C	APHA (1985)	10 mg/L
Chemical Oxygen Demand	Std Method No. 508C	APHA (1985)	4 mg/L
Total Organic Carbon	Std Method No. 505	APHA (1985)	0.1 mg/L
Total Coliform	Std Method No. 909A	APHA (1985)	1/100 ml
Fecal Coliform	Std Method No. 909C	APHA (1985)	1/100 ml

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APPENDIX B

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Table B–1. Whatcom Dairy #1, Well Construction Summary.

Well ID	Date Installed	Initial Depth (TOC,ft)	Well Elevation (TOC)	Date Deepened	Final Depth (TOC,ft)	Well Elevation (TOC)	Well Elevation (2/27/91) (TOC)	Casing Material	Screen Type
MW-1	02/26/90	11.5	126.66	05/14/90	16.6	126.42	126.44	Galv.Steel	Stainless
MW-2	02/26/90	11.5	126.26	05/14/90	14.7	125.17	125.19	Galv.Steel	Stainless
MW-3	02/26/90	11.4	126.03	05/15/90	17.8	126.95	126.93	Galv.Steel	Stainless
MW-4	02/27/90	11.5	125.00*	05/15/90	14.5	124.12	124.13	Galv.Steel	Stainless
MW-5	02/27/90	11.6	124.96	NA	NA	124.96	124.84	Galv.Steel	Stainless
MW-6	02/27/90	11.8	125.93	05/15/90	DC'd	NA	NA	Galv.Steel	Stainless
MW-6A	07/30/90	14.4	126.33	11/28/90	17.8	125.64	125.64	Galv.Steel	Stainless
MW-7A	11/28/90	20.6	125.97	NA	NA	125.97	125.97	Galv.Steel	Stainless
MW-8	07/13/92	13.5	110.68	NA	NA	NA	NA	Galv.Steel	Stainless

NA= Not Applicable TOC= Top of Casing DC'd= Well Decommissioned

* Arbitrary Datum, Approximately Mean Sea Level

Table B–2. Whatcom Dairy #2, Well Construction Summary.

Well ID	Total Depth (feet)	Meas. Pt. Elevation (feet,MSL)	Date Installed	Diameter (inches)	Casing Material	Top of Screen (feet,bgs)	Bottom of Screen (feet,bgs)	Screen Type	Slot Size
MW1	16.2	98.12	11/28/90	1.25	Galv.Steel	14.2	16.2	Stainless	60 Gze
MW2	16.0	97.36	11/28/90	1.25	Galv.Steel	14.0	16.0	Stainless	60 Gze
MW3	18.1	100.01	02/26/91	1.25	Galv.Steel	16.1	18.1	Stainless	60 Gze
MW4	15.8	97.76	02/26/91	1.25	Galv.Steel	13.8	15.8	Stainless	60 Gze
MW5	14.0	96.85	07/13/92	1.25	Galv.Steel	12.0	14.0	Stainless	60 Gze
MW6	14.0	94.52	07/13/92	1.25	Galv.Steel	12.0	14.0	Stainless	60 Gze
Irrig. Well	33	96.88	6/73	36	Concrete	18	33	Perforated	5/8 by 5/8

Table B–3. Hornby Dairy, Well Construction Summary.

Well ID	Total Depth (feet,GSD)	Measuring Point Elevation (feet, MSL)	Screened Interval (feet,BGS)	Diameter (inches)	Casing Material	Screen Material	Use	Slot Size
MW-1	13.4	719.38	11.4-13.4	1.25	Galv.Steel	Stainless	Monitoring	60 Gze
MW-2	13.9	717.55	11.9-13.9	1.25	Galv.Steel	Stainless	Monitoring	60 Gze
MW-3	13.9	716.10	11.9-13.9	1.25	Galv.Steel	Stainless	Monitoring	60 Gze
MW-4	13.6	717.03	11.6-13.6	1.25	Galv.Steel	Stainless	Monitoring	60 Gze
MW-5	13.6	716.57	11.6-13.6	1.25	Galv.Steel	Stainless	Monitoring	60 Gze
Davis	87	712.2	85	6	Steel	None	Domestic	None
Radach	60	720.89	60	6	Steel	None	Domestic	None
Hefty	110	712.45	110	6	Steel	None	Domestic	None

BGS= Below Ground Surface

MSL= Approximate Mean Sea Level

Table B–4. Sheridan Dairy, Well Construction Summary.

Well ID	Total Depth (feet, BGS)	Measuring Point Elevation (feet,MSL)	Diameter (inches)	Top of Screen (feet,BGS)	Bottom of Screen (feet,BGS)	Casing	Screen	Slot Size
MW1	31.5	199.82	1.25	29.5	31.5	Galv. Stee	Stainless	60 Gze
MW2	32.8	199.40	1.25	30.8	32.8	Galv. Stee	Stainless	60 Gze
MW3	27.9	201.07	1.25	25.9	27.9	Galv. Stee	Stainless	60 Gze
MW4	27.6	203.12	1.25	25.6	27.6	Galv. Stee	Stainless	60 Gze

BGS= Below Ground Surface.

MSL= Approximate Mean Sea Level.

APPENDIX C

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Table C–1. Edaleen Dairy Lagoon Water Level Measurements. (Corrected for Measuring Point (MP) Changes)

Site Name	Date	Top of Casing	X	Y	Depth to Water (feet)	Water Level Elevation (MSL, feet)
MW1	02/28/90	126.66	1609964	727686	7.68	118.98
MW1	03/07/90	126.66	1609964	727686	8.47	118.19
MW1	04/10/90	126.66	1609964	727686	9.94	116.72
MW1	05/16/90	126.42	1609964	727686	10.84	115.58
MW1	06/19/90	126.42	1609964	727686	9.89	116.53
MW1	07/31/90	126.42	1609964	727686	12.08	114.34
MW1	08/27/90	126.42	1609964	727686	14.24	112.18
MW1	09/25/90	126.42	1609964	727686	14.27	112.15
MW1	10/22/90	126.42	1609964	727686	13.77	112.65
MW1	11/26/90	126.42	1609964	727686	6.35	120.07
MW1	12/18/90	126.42	1609964	727686	6.03	120.39
MW1	01/22/91	126.42	1609964	727686	8.31	118.11
MW1	02/26/91	126.42	1609964	727686	7.88	118.54
MW1	08/13/91	126.42	1609964	727686	12.98	113.44
MW1	10/28/91	126.42	1609964	727686	13.52	112.9
MW1	04/27/92	126.42	1609964	727686	10.95	115.47
MW1	07/14/92	126.42	1609964	727686	12.44	113.98
MW1	10/19/92	126.42	1609964	727686	13.7	112.72
MW1	01/11/93	126.42	1609964	727686	9.38	117.04
MW1	04/26/93	126.42	1609964	727686	9.17	117.25
MW2	02/28/90	126.26	1610098	727680	7.34	118.92
MW2	03/07/90	126.26	1610098	727680	8.09	118.17
MW2	04/10/90	126.26	1610098	727680	9.65	116.61
MW2	05/16/90	125.17	1610098	727680	9.71	115.46
MW2	06/19/90	125.17	1610098	727680	8.8	116.37
MW2	07/31/90	125.17	1610098	727680	11.08	114.09
MW2	08/27/90	125.17	1610098	727680	12.89	112.28
MW2	09/25/90	125.17	1610098	727680	13.15	112.02
MW2	10/22/90	125.17	1610098	727680	12.58	112.59
MW2	11/26/90	125.17	1610098	727680	5.29	119.88
MW2	12/18/90	125.17	1610098	727680	4.99	120.18
MW2	01/22/91	125.17	1610098	727680	7.22	117.95
MW2	02/26/91	125.17	1610098	727680	6.78	118.39
MW2	08/13/91	125.17	1610098	727680	11.65	113.52
MW2	10/28/91	125.17	1610098	727680	12.3	112.87
MW2	04/27/92	125.17	1610098	727680	9.85	115.32
MW2	07/14/92	125.17	1610098	727680	11.29	113.88
MW2	10/19/92	125.17	1610098	727680	12.49	112.68
MW2	01/11/93	125.17	1610098	727680	8.13	117.04
MW2	04/26/93	125.17	1610098	727680	8.08	117.09

Table C-1. Continued.

Site Name	Date	Top of Casing	X	Y	Depth to Water (feet)	Water Level Elevation (MSL, feet)
MW3	02/28/90	126.03	1610306	727680	7.23	118.8
MW3	03/07/90	126.03	1610306	727680	7.93	118.1
MW3	04/10/90	126.03	1610306	727680	9.52	116.51
MW3	05/16/90	126.95	1610306	727680	11.8	115.15
MW3	06/19/90	126.95	1610306	727680	10.87	116.08
MW3	07/31/90	126.95	1610306	727680	13	113.95
MW3	08/27/90	126.95	1610306	727680	14.4	112.55
MW3	09/25/90	126.95	1610306	727680	15.03	111.92
MW3	10/22/90	126.95	1610306	727680	14.31	112.64
MW3	11/26/90	126.95	1610306	727680	7.31	119.64
MW3	12/18/90	126.95	1610306	727680	6.97	119.98
MW3	01/22/91	126.95	1610306	727680	9.2	117.75
MW3	02/26/91	126.95	1610306	727680	8.72	118.23
MW3	08/13/91	126.95	1610306	727680	13.8	113.15
MW3	10/28/91	126.95	1610306	727680	14.25	112.7
MW3	04/27/92	126.95	1610306	727680	11.74	115.21
MW3	07/14/92	126.95	1610306	727680	13.26	113.69
MW3	10/19/92	126.95	1610306	727680	14.48	112.47
MW3	01/11/93	126.95	1610306	727680	10.21	116.74
MW3	04/26/93	126.95	1610306	727680	10.02	116.93
MW4	02/28/90	125.00	1610634	727542	6.13	118.87
MW4	03/07/90	125.00	1610634	727542	7.54	117.46
MW4	04/10/90	125.00	1610634	727542	8.81	116.19
MW4	05/16/90	124.12	1610634	727542	9.75	114.37
MW4	06/19/90	124.12	1610634	727542	8.95	115.17
MW4	07/31/90	124.12	1610634	727542	11.05	113.07
MW4	08/27/90	124.12	1610634	727542	12.62	111.5
MW4	09/25/90	124.12	1610634	727542	12.76	111.36
MW4	10/22/90	124.12	1610634	727542	12.11	112.01
MW4	11/26/90	124.12	1610634	727542	5.59	118.53
MW4	12/18/90	124.12	1610634	727542	5.23	118.89
MW4	01/22/91	124.12	1610634	727542	7.3	116.82
MW4	02/26/91	124.12	1610634	727542	6.73	117.39
MW4	08/13/91	124.12	1610634	727542	11.54	112.58
MW4	10/28/91	124.12	1610634	727542	12.07	112.05
MW4	04/27/92	124.12	1610634	727542	9.81	114.31
MW4	07/14/92	124.12	1610634	727542	11.1	113.02
MW4	10/19/92	124.12	1610634	727542	12.08	112.04
MW4	01/11/93	124.12	1610634	727542	8.24	115.88
MW4	04/26/93	124.12	1610634	727542	8.03	116.09

Table C-1. Continued.

Site Name	Date	Top of Casing	X	Y	Depth to Water (feet)	Water Level Elevation (MSL, feet)
MW5	02/28/90	124.96	1610280	728200	4.19	120.77
MW5	03/07/90	124.96	1610280	728200	5.2	119.76
MW5	04/10/90	124.96	1610280	728200	6.78	118.18
MW5	05/16/90	124.96	1610280	728200	7.7	117.26
MW5	06/19/90	124.96	1610280	728200	6.9	118.06
MW5	07/31/90	124.84	1610280	728200	6.26	118.58
MW5	08/27/90	124.84	1610280	728200	11.07	113.77
MW5	10/22/90	124.84	1610280	728200	10.51	114.33
MW5	11/26/90	124.84	1610280	728200	3.2	121.64
MW5	12/18/90	124.84	1610280	728200	2.96	121.88
MW5	01/22/91	124.84	1610280	728200	5.19	119.65
MW5	02/26/91	124.84	1610280	728200	4.72	120.12
MW5	08/13/91	124.84	1610280	728200	10.17	114.67
MW5	10/28/91	124.84	1610280	728200	10.5	114.34
MW5	04/27/92	124.84	1610280	728200	7.8	117.04
MW5	07/14/92	124.84	1610280	728200	9.46	115.38
MW5	10/20/92	124.84	1610280	728200	10.71	114.13
MW5	01/11/93	124.84	1610280	728200	6.39	118.45
MW5	04/26/93	124.84	1610280	728200	6.16	118.68
MW6	02/28/90	125.93	1610592	727662	7.37	118.56
MW6	03/07/90	125.93	1610592	727662	7.6	118.33
MW6	04/10/90	125.93	1610592	727662	8.93	117
MW6A	07/31/90	126.33	1610592	727662	12.91	113.42
MW6A	10/22/90	126.33	1610592	727662	12.93	113.4
MW6A	11/26/90	126.33	1610592	727662	7.51	118.82
MW6A	12/18/90	125.64	1610592	727662	6.5	119.14
MW6A	01/22/91	125.64	1610592	727662	8.57	117.07
MW6A	02/26/91	125.64	1610592	727662	8.02	117.62
MW6A	08/13/91	125.64	1610592	727662	12.8	112.84
MW6A	10/28/91	125.64	1610592	727662	13.29	112.35
MW6A	04/28/92	125.64	1610592	727662	11.09	114.55
MW6A	07/14/92	125.64	1610592	727662	12.25	113.39
MW6A	10/19/92	125.64	1610592	727662	13.32	112.32
MW6A	01/11/93	125.64	1610592	727662	9.57	116.07
MW6A	04/26/93	125.64	1610592	727662	9.36	116.28
MW7A	12/18/90	125.97	1610310	727550	6.2	119.77
MW7A	01/22/91	125.97	1610310	727550	8.64	117.33
MW7A	02/26/91	125.97	1610310	727550	8.12	117.85
MW7A	08/13/91	125.97	1610310	727550	13.03	112.94
MW7A	10/28/91	125.97	1610310	727550	13.62	112.35
MW7A	04/27/92	125.97	1610310	727550	11.13	114.84
MW7A	07/14/92	125.97	1610310	727550	12.62	113.35
MW7A	10/19/92	125.97	1610310	727550	13.71	112.26
MW7A	01/11/93	125.97	1610310	727550	9.62	116.35

Table C-1. Continued.

Site Name	Date	Top of Casing	X	Y	Depth to Water (feet)	Water Level Elevation (MSL, feet)
MW7A	04/26/93	125.97	1610310	727550	9.49	116.48
MW8	07/14/92	110.68	1611100	726080	2.42	108.26
MW8	10/19/92	110.68	1611100	726080	2.43	108.25
MW8	01/11/93	110.68	1611100	726080	1.38	109.3
MW8	04/26/93	110.68	1611100	726080	1.31	109.37

Table C–2. Whatcom Dairy #2, Water Level Measurements.

Site Name	Date	Top of Casing (feet, MSL)	X	Y	Depth to Water (feet)	Water Elev. (feet, MSL)
MW1	02/27/91	98.12	1602280	717680	4.78	93.34
MW1	05/21/91	98.12	1602280	717680	5.45	92.67
MW1	08/13/91	98.12	1602280	717680	7.35	90.77
MW1	10/28/91	98.12	1602280	717680	6.26	91.86
MW2	02/27/91	97.36	1602399	717456	4.88	92.48
MW2	05/21/91	97.36	1602399	717456	5.39	91.97
MW2	08/13/91	97.36	1602399	717456	6.72	90.64
MW2	10/28/91	97.36	1602399	717456	5.83	91.53
MW2	04/27/92	97.36	1602399	717456	5.17	92.19
MW2	07/14/92	97.36	1602399	717456	5.47	91.89
MW2	10/19/92	97.36	1602399	717456	6.25	91.11
MW2	01/11/93	97.36	1602399	717456	3.68	93.68
MW2	04/26/93	97.36	1602399	717456	4.9	92.46
MW3	02/27/91	100.01	1602552	717456	7.39	92.62
MW3	05/21/91	100.01	1602552	717456	7.78	92.23
MW3	08/13/91	100.01	1602552	717456	9.19	90.82
MW3	10/28/91	100.01	1602552	717456	8.29	91.72
MW3	04/27/92	100.01	1602552	717456	7.73	92.28
MW3	07/14/92	100.01	1602552	717456	8.11	91.9
MW3	10/19/92	100.01	1602552	717456	8.66	91.35
MW3	01/11/93	100.01	1602552	717456	6.11	93.9
MW3	04/26/93	100.01	1602552	717456	7.35	92.66
MW4	02/27/91	97.76	1602708	717456	5	92.76
MW4	05/21/91	97.76	1602708	717456	5.44	92.32
MW4	08/13/91	97.76	1602708	717456	6.67	91.09
MW4	10/28/91	97.76	1602708	717456	5.91	91.85
MW4	04/27/92	97.76	1602708	717456	5.34	92.42
MW4	07/14/92	97.76	1602708	717456	5.82	91.94
MW4	10/19/92	97.76	1602708	717456	6.29	91.47
MW4	01/11/93	97.76	1602708	717456	3.8	93.96
MW4	04/26/93	97.76	1602708	717456	4.98	92.78
MW5	07/14/92	96.85	1602552	717695	4.65	92.2
MW5	10/19/92	96.85	1602552	717695	5.11	91.74
MW5	01/11/93	96.85	1602552	717695	2.5	94.35
MW5	04/26/93	96.85	1602552	717695	3.51	93.34
MW6	07/14/92	94.52	1602552	717306	2.85	91.67
MW6	10/19/92	94.52	1602552	717306	3.51	91.01
MW6	01/11/93	94.52	1602552	717306	0.83	93.69
MW6	04/26/93	94.52	1602552	717306	2.21	92.31
New Irrigation Well	04/27/92	96.88	1602995	717602	4.11	92.77
New Irrigation Well	10/19/92	96.88	1602995	717602	5.36	91.52
New Irrigation Well	01/11/93	96.88	1602995	717602	2.67	94.21
New Irrigation Well	04/26/93	96.88	1602995	717602	3.76	93.12

Table C-2. Continued. Site Name	Date	Top of Casing (feet, MSL)	X	Y	Depth to Water (feet)	Water Elev. (feet, MSL)
LAGOON BERM	02/27/91	101.93	0	0	2	99.9
LAGOON BERM	08/13/91	101.93	0	0	4	97.9
LAGOON BERM	10/28/91	101.93	0	0	7	94.9
LAGOON BERM	04/27/92	101.93	0	0	8	94
LAGOON BERM	07/14/92	101.93	0	0	6	96
LAGOON BERM	10/19/92	101.93	0	0	3	98.9
LAGOON BERM	04/26/93	101.93	0	0	4	98

MSL= Mean Sea Level, Approximate.

Table C-3. Hornby Dairy, Water Level Measurements.

Site Name	Date	Top of Casing (feet,MSL)	X	Y	Depth to Water (feet)	Water Elevation (feet,MSL)
MW1	04/25/90	719.38	2136862	343717	9.83	709.55
MW1	05/02/90	719.38	2136862	343717	9.78	709.6
MW1	07/02/90	719.38	2136862	343717	9.57	709.81
MW1	11/06/90	719.38	2136862	343717	8.85	710.53
MW1	01/28/91	719.38	2136862	343717	9.51	709.87
MW1	06/08/92	719.38	2136862	343717	10.19	709.19
MW1	09/14/92	719.38	2136862	343717	10.44	708.94
MW1	12/14/92	719.38	2136862	343717	10.45	708.93
MW1	03/15/93	719.38	2136862	343717	10.13	709.25
MW2	04/25/90	717.55	2136457	344044	9.05	708.5
MW2	05/02/90	717.55	2136457	344044	8.94	708.61
MW2	07/02/90	717.55	2136457	344044	8.52	709.03
MW2	11/06/90	717.55	2136457	344044	7.26	710.29
MW2	01/29/91	717.55	2136457	344044	8.8	708.75
MW2	06/08/92	717.55	2136457	344044	8.53	709.02
MW2	09/14/92	717.55	2136457	344044	7.96	709.59
MW2	12/14/92	717.55	2136457	344044	9	708.55
MW2	03/15/93	717.55	2136457	344044	9.28	708.27
MW3	04/25/90	716.1	2136440	343386	8.05	708.05
MW3	05/02/90	716.1	2136440	343386	7.07	709.03
MW3	07/02/90	716.1	2136440	343386	6.9	709.2
MW3	11/06/90	716.1	2136440	343386	8.5	707.6
MW3	01/29/91	716.1	2136440	343386	9.02	707.08
MW3	06/08/92	716.1	2136440	343386	8.66	707.44
MW3	09/14/92	716.1	2136440	343386	8.75	707.35
MW3	12/14/92	716.1	2136440	343386	9.37	706.73
MW3	03/15/93	716.1	2136440	343386	9.17	706.93
MW4	04/25/90	717.03	2136446	343715	9.29	707.74
MW4	05/02/90	717.03	2136446	343715	7.65	709.38
MW4	07/02/90	717.03	2136446	343715	7.88	709.15
MW4	11/06/90	717.03	2136446	343715	8.74	708.29
MW4	01/29/91	717.03	2136446	343715	9.51	707.52
MW4	10/24/91	717.03	2136446	343715	8.46	708.57
MW4	06/08/92	717.03	2136446	343715	9.72	707.31
MW4	09/14/92	717.03	2136446	343715	9.44	707.59
MW4	12/14/92	717.03	2136446	343715	10.22	706.81
MW4	03/15/93	717.03	2136446	343715	10.08	706.95
MW5	04/25/90	716.57	2136572	343214	8.79	707.78
MW5	05/02/90	716.57	2136572	343214	8.93	707.64
MW5	07/02/90	716.57	2136572	343214	8.8	707.77
MW5	11/06/90	716.57	2136572	343214	9.14	707.43
MW5	01/29/91	716.57	2136572	343214	9.77	706.8
MW5	06/08/92	716.57	2136572	343214	9.95	706.62

Table C-3. Continued.

Site Name	Date	Top of Casing (feet,MSL)	X	Y	Depth to Water (feet)	Water Elevation (feet,MSL)
MW5	09/14/92	716.57	2136572	343214	10.22	706.35
MW5	12/14/92	716.57	2136572	343214	9.98	706.59
MW5	03/15/93	716.57	2136572	343214	9.55	707.02
STAFF GAGE	04/25/90	703.76	2135684	343594	2.66	701.1
STAFF GAGE	05/02/90	703.76	2135684	343594	2.51	701.25
STAFF GAGE	07/02/90	703.76	2135684	343594	2.76	701
STAFF GAGE	11/07/90	703.76	2135684	343594	2.75	701.01
STAFF GAGE	01/29/91	703.76	2135684	343594	1.5	702.3
STAFF GAGE	09/14/92	703.76	2135684	343594	2.5	701.3
IRRIGATION DRAIN	05/02/90	717.62	2136708	343846	9.65	707.97
IRRIGATION DRAIN	07/02/90	717.62	2136708	343846	9.73	707.89
IRRIGATION DRAIN	11/06/90	717.62	2136708	343846	9.8	707.82
IRRIGATION DRAIN	01/29/91	717.62	2136708	343846	9.8	707.8
DAVIS	04/25/90	712.2	2136428	343035	5.74	706.46
DAVIS	05/02/90	712.2	2136428	343035	5.61	706.59
DAVIS	07/03/90	712.2	2136428	343035	4.62	707.58
DAVIS	11/06/90	712.2	2136428	343035	5	707.2
DAVIS	01/29/91	712.2	2136428	343035	5.53	706.67
DAVIS	10/25/91	712.2	2136428	343035	4.78	707.42
DAVIS	06/08/92	712.2	2136428	343035	7.33	704.87
DAVIS	06/09/92	712.2	2136428	343035	5.42	706.78
DAVIS	09/14/92	712.2	2136428	343035	5.7	706.5
DAVIS	12/14/92	712.2	2136428	343035	6.35	705.85
DAVIS	03/15/93	712.2	2136428	343035	5.86	706.34
RADACH	05/02/90	720.89	2137674	343060	8.68	712.21
RADACH	07/02/90	720.89	2137674	343060	7.2	713.69
RADACH	11/06/90	720.89	2137674	343060	7.92	712.97
RADACH	01/29/91	720.89	2137674	343060	9.16	711.73
RADACH	09/15/92	720.89	2137674	343060	7.74	713.15
RADACH	12/14/92	720.89	2137674	343060	8.93	711.96
RADACH	03/15/93	720.89	2137674	343060	8.53	712.36
HEFTY	05/02/90	712.45	2135281	346466	8.75	703.7
HEFTY	07/02/90	712.45	2135281	346466	8.92	703.53
HEFTY	11/07/90	712.45	2135281	346466	8.05	704.4
HEFTY	01/29/91	712.45	2135281	346466	8.82	703.63
HEFTY	09/14/92	712.45	2135281	346466	6.62	705.83
HEFTY	12/14/92	712.45	2135281	346466	8.41	704.04
SETTLING POND #1	04/25/90	721.1	0	0	1	720.1
SETTLING POND #1	05/02/90	721.1	0	0	1.5	719.6
SETTLING POND #1	11/06/90	721.1	0	0	2.5	718.6
SETTLING POND #1	01/29/91	721.1	0	0	2	719.1
SETTLING POND #1	06/08/92	721.1	0	0	-2	723
SETTLING POND #1	09/15/92	721.1	0	0	2	719
SETTLING POND #1	12/14/92	721.1	0	0	2	719
SETTLING POND #1	03/15/93	721.1	0	0	1	720

Table C-3. Continued.

Site Name	Date	Top of Casing (feet,MSL)	X	Y	Depth to Water (feet)	Water Elevation (feet,MSL)
SETTLING POND #2	05/02/90	721.1	0	0	0	721
SETTLING POND #2	11/06/90	721.1	0	0	1	720.1
SETTLING POND #2	01/29/91	721.1	0	0	2	719.1
SETTLING POND #2	09/15/92	721.1	0	0	2	719.1
SETTLING POND #2	12/14/92	721.1	0	0	1	720
SETTLING POND #2	03/15/93	721.1	0	0	1	720
MAIN LAGOON	04/25/90	720.6	0	0	5	715.6
MAIN LAGOON	05/02/90	720.6	0	0	5.5	715.1
MAIN LAGOON	07/03/90	720.6	0	0	4	716.6
MAIN LAGOON	11/06/90	720.6	0	0	5	715.6
MAIN LAGOON	01/29/91	720.6	0	0	4	716.6
MAIN LAGOON	09/15/92	720.6	0	0	4	716.6
MAIN LAGOON	12/14/92	720.6	0	0	5	716
MAIN LAGOON	03/15/93	720.6	0	0	1	720

Table C-4. Sheridan Dairy, Water Level Measurements.

Site Name	Date	Top of Casing (MSL, feet)	State Plane Coordinates X	Y	Depth to Water (LSD, feet)	Depth to Water (TOC,feet)	Water Elevation (MSL, feet)
Lagoon	06/18/91	199	0	0	8	NA	191
Lagoon	01/07/92	199	0	0	4	NA	195
Lagoon	04/14/92	199	0	0	9	NA	190
MW1	06/18/91	199.82	1351384	487814	7.5	9.35	190.47
MW1	09/16/91	199.82	1351384	487814	8.3	10.24	189.58
MW1	01/07/92	199.82	1351384	487814	5.3	7.24	192.58
MW1	04/14/92	199.82	1351384	487814	6.9	8.78	191.04
MW2	06/18/91	199.4	1351487	487784	9.3	9.85	189.55
MW2	09/16/91	199.4	1351487	487784	9.4	9.96	189.44
MW2	01/07/92	199.4	1351487	487784	6.5	7.06	192.34
MW2	04/14/92	199.4	1351487	487784	7.8	8.35	191.05
MW3	06/18/91	201.07	1351574	487758	8.5	10.76	190.31
MW3	09/16/91	201.07	1351574	487758	9.4	11.68	189.39
MW3	01/07/92	201.07	1351574	487758	6.8	9.05	192.02
MW3	04/14/92	201.07	1351574	487758	7.9	10.18	190.89
MW4	06/18/91	203.12	1351518	487962	9.1	11.89	191.23
MW4	09/16/91	203.12	1351518	487962	10.5	13.26	189.86
MW4	01/07/92	203.12	1351518	487962	6.6	9.41	193.71
MW4	04/14/92	203.12	1351518	487962	8.4	11.16	191.96

LSD= Land Surface Datum.
TOC= Top of Casing.
MSL= Mean Sea Level.

APPENDIX D

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APPENDIX D. QUALITY ASSURANCE

General

In addition to calibration standards, spikes, and laboratory duplicates, field quality assurance samples consisted of blind duplicates and TOC transport blanks. A blind duplicate, used to estimate analytical precision, was obtained for each parameter during each sampling event. Duplicate results, relative percent differences (RPDs, the ratio of the difference of duplicate results and their mean expressed as a percent) and TOC transport results are shown in Tables D-1 through D-4.

The quality of most of the data is good. Data requiring qualification for each of the lagoon studies are discussed below.

Whatcom Dairy #1

RPDs are generally less than 15 percent for most parameters. RPD's for COD (0 to 93%) and TOC (1 to 98%) were highly variable. The cause of this wide variation is unknown. In addition, TOC transport blanks were tested for six of the sampling events. The concentrations ranged from 0.2 to 0.8 mg/L with a mean of 0.4 mg/L. Concentrations less than 2.0 mg/L (five times the transport blank concentration) are qualified with a "B".

Nitrate+nitrite-N results for the April 10, 1990 sampling show an RPD of 175%. This result is probably due to laboratory error for that specific sample and is not considered representative of laboratory precision based on quality assurance results of other sampling events. Nitrate+nitrite-N data are estimated for two sampling events (December 18, 1990 and January 22, 1991) because the laboratory did not use a nitrite ($NO2$) standard. Values are flagged with a "J" as estimated values.

Samples were tested for total persulfate nitrogen (TPN) beginning in November 1990. TPN results should represent the total of organic and inorganic (ammonia-N and nitrate+nitrite-N) nitrogen. In general, TPN results should correspond to and be greater than the sum of nitrate+nitrite-N and ammonia-N results. For the first sampling the correspondence is generally good, however, in subsequent sampling events the correspondence is poor and inconsistent. The cause of the inconsistency is unknown. There are insufficient reliable TPN data to discuss concentration variations over time.

Total phosphorus for the July 31-August 1, 1990 sampling event are estimated because of interferences and are flagged with a "J".
Chloride results for one sampling event (September 25, 1990) were inconsistent compared to previous and subsequent chloride results, TDS results, and field specific conductance readings. The cause of the inconsistency could not be identified therefore chloride data for this sampling event are not reported.
Bacteriological samples for the December sampling exceeded the 30-hour holding time and results are not reported.

Whatcom Dairy #2

RPDs were generally less than 25% for most parameters. Exceptions are chemical oxygen demand (33%), total organic carbon (28%), nitrate+nitrite as N (127%) and total phosphorus (40%) for February, and total dissolved solids (29%) for May. The high nitrate+nitrite-N RPD occurred near the method detection limit, and therefore is not necessarily representative of analytical precision at higher concentrations. August duplicate results for total coliform bacteria were inconsistent; one sample showed no bacteria and the other showed five organisms/100mL. Ammonia-N for February was estimated because testing was completed after the recommended holding time. Total persulfate nitrogen results for the February sampling were estimated because of matrix interference.

The concentrations for TOC transport blanks were less than 1 mg/L and no qualification of the data is necessary. The October result for the lagoon TOC concentration was estimated because of matrix interference.

Hornby Dairy

RPDs are generally less than 20% for most parameters. Exceptions are TOC (70%, January 1991); ammonia-N (48%, January 1991), and total phosphate-P (25%, July 1990). The cause of the low precision for TOC for the January sampling round is not known. Ammonia-N results were designated as estimates for the January round because of high dilutions used during analysis. Nitrate+nitrite-N results were designated as estimates for the January sampling round because a nitrite calibration standard inadvertently was not run. With the exception of the wastewater sample, TPN results which represent the total of organic and inorganic (ammonia-N and nitrate+nitrite-N) nitrogen are consistent with ammonia-N and nitrate+nitrite-N results. The cause for the discrepancy in the wastewater sample (total inorganic nitrogen 19.0 mg/L and TPN not detected) is not known.

The TOC concentrations for transport blanks ranged from 0.3 to 0.4 mg/L. Because all sample TOC concentrations are substantially higher than blank concentrations, no qualification of the data is necessary. The TOC results for November 1990 were rejected because they were inconsistent with 1) COD readings of the same sampling event and 2) previous and subsequent TOC results.

Sheridan Dairy

Most of the RPDs are less than 25% and frequently less than 5%. The September results showed high RPDs for total dissolved solids (58%), chemical oxygen demand (97%) and total phosphorus (105%). The RPD for TOC was 46% for the April sampling. The cause of the poor precision for these parameters for these sampling events is not known. In the results section of this report the analyte concentrations for field duplicates are reported as the mean of the duplicate results.

Other qualified data are discussed as follows. Lagoon sample results are estimated for many parameters because of interference due to high suspended solids in the samples. All TOC data are estimated for the September sampling because results from dual injections showed poor precision.

The concentrations for TOC transport blanks were less than the quantitation limit (1 mg/L) and no qualification of the data due to blank contamination is necessary.

Table D-1. Whatcom Dairy #1, Quality Assurance Results, February 1990 to April 1993
(Units=mg/L unless specified otherwise)

Sample Event	TDS	COD	TOC	Ammonia-N	Nitrate + Nitrite-N	Total Phosphorus	Chloride	Total Persul-N	T. Coli. (#/100ml)	F. Coli. (#/100ml)	Transport TOC	Iron
02/28/90	140	8.1	7.11	0.02	5.99	0.02	2.2	NT	3U	3U		NT
	127	5.1	8.38	0.01	5.91	0.04	2.2	NT	3U	3U		NT
RPD(%)=	9.7	45.5	16.4	66.7	1.3	66.7	0.0					
03/07/90	137	7.5	6.62	0.03	8.33	0.01U	3.85	NT	1U	1U		NT
	116	9.8	5.77	0.03	9.38	0.07	3.99	NT	1U	1U		NT
RPD(%)=	16.6	26.6	13.7	0.0	11.9		3.6					
04/10/90	145	6.5	3.07	0.02	8.82	0.01U	3.85	NT	1U	1U		NT
	149	7.1	3.04	0.02	0.6	0.01U	3.79	NT	1U	3U		NT
RPD(%)=	2.7	8.8	1.0	0.0	174.5		1.6					
05/16/90	207	6.7	9.67	0.06	2.9	0.017	12.9	NT	1U	1U	0.85	NT
	180	10.7	15.1	0.06	2.82	0.014	14	NT	1U	1U		NT
RPD(%)=	14.0	46.0	43.8	0.0	2.8	19.4	8.2					
06/19/90	176	5.1	0.5U	0.054	2.49	0.013	14.3	NT	1U	1U		NT
	167	13.9	1.35B	0.057	2.76	0.007	14.7	NT	1U	1U		NT
RPD(%)=	5.2	92.6		5.4	10.3	60.0	2.8					
07/31/90	183	13.2	8.67	0.07	0.48	0.01J	20.2	NT	1U	1U		NT
	189	16.2	6.84	0.07	0.5	0.02J	22.1	NT	1U	1U		NT
RPD(%)=	3.2	20.4	23.6	0.0	4.1		9.0					
08/27/90	323	11	17.9	0.126	0.01U	0.045	42.9	NT	1U	1U	0.39	NT
	329	13	29.4	0.125	0.01U	0.042	41.5	NT	1U	1U		NT
RPD(%)=	1.8	16.7	48.6	0.8		6.9	3.3					
09/25/90	390	19	18.8	0.129	0.23	0.042	2.0R	NT	1U	1U		NT
	460	15	18.6	0.131	0.21	0.042	1.3R	NT	1U	1U		NT
RPD(%)=	16.5	23.5	1.1	1.5	9.1	0.0						
10/22/90	417	22	70	0.228	0.01U	0.248	69.7	NT	1U	1U	0.26	NT
	527	11	65.7	0.221	0.01U	0.259	68.9	NT	1U	1U		NT
RPD(%)=	23.3	66.7	6.3	3.1		4.3	1.2					
11/27/90	390	29	40	0.12	1.99	0.03	56.6	2.83	1UX	1U	0.16	NT
	390	38	34.4	0.11	1.88	0.03	56.1	2.77	1UX	1U		NT
RPD(%)=	0.0	26.9	15.1	8.7	5.7	0.0	0.9	2.1				

Table D-1 Continued.

Sample Event	TDS	COD	TOC	Ammonia-N	Nitrate + Nitrite-N	Total Phosphorus	Chloride	Total Persul-N	T. Coli. (#/100ml)	F. Coli. (#/100ml)	Transport TOC	Iron
12/18/90	311	38	7.9	0.217	11.6	0.034	13.6	11.1	OHT	OHT		NT
	326	35	7.31	0.219	11.4	0.035	13	11.3	OHT	OHT		NT
RPD(%)=	4.7	8.2	7.8	0.9	1.7	2.9	4.5	1.8				
01/22/91	384	10U	13.2	0.206	24.9	0.005U	14.1	27	1U	1U	0.33	NT
	380	10U	38.7	0.241	24.4	0.005U	13.5	26.2	1U	1U		NT
RPD(%)=	1.0		98.3	15.7	2.0		4.3	3.0				
02/26/91	474	10U	22.2	0.146	0.231	0.021	21.4	0.62	1U	1U	0.47	NT
	476	10U	14.3	0.159	0.228	0.015	21.8	0.53	1U	1U		NT
RPD(%)=	0.4		43.3	8.5	1.3	33.3	1.9	15.7				
08/14/91	846	110	45.4	0.51	0.07	0.06	85	NT	1U	1U	1U	NT
	867	117	43.3	0.6	0.16	0.06	92.2	NT	1U	1U		NT
RPD(%)=	2.5	6.2	4.7	16.2	78.3	0.0	8.1					
10/29/91	934	130	57.2	77	0.04	0.04	100	NT	1U	1U	1U	NT
	934	160	50.9	85	0.02U	0.05	93.1	NT	1U	1U		NT
RPD(%)=	0.0	20.7	11.7	9.9		22.2	7.1					
04/28/92	522	86	38.4	36	0.01U	0.111	38	NT	1UX	1UX	NT	NT
	507	85	37.8	37.7	0.01U	0.112	38	NT	1UX	1UX		NT
RPD(%)=	2.9	1.2	1.6	4.6		0.9	0.0					
07/15/92	530	54.2	14.1	15	0.05U	0.046	36.2	NT	1U	1U	NT	24.9
	524	57	17	15.1	0.05U	0.035	35.7	NT	1U	1U		24.9
RPD(%)=	1.1	5.0	18.6	0.7		27.2	1.4					0.0
10/20/92	700	120	42.4	81.5	0.2U	0.06	66.3	NT	1U	1U	NT	NT
	742	110	45.5	84	0.2U	0.08	66.5	NT	1U	1U		NT
RPD(%)=	5.8	8.7	7.1	3.0		28.6	0.3					
01/12/93	646	90.7	43.6	77.8	0.436	0.028	47.1	NT	1U	1U	NT	NT
	630	95.4	42.1	79.6	0.453	0.029	47.5	NT	1U	1U		NT
RPD(%)=	2.5	5.1	3.5	2.3	3.8	3.5	0.8					
04/27/93	425	19	8.4	6.76	0.01U	0.018	27.3	NT	NT	NT	NT	12.7
	395	24	8.3	6.81	0.01U	0.02	27.4	NT	NT	NT		12.6
RPD(%)=	7.3	23.3	1.2	0.7		10.5	0.4					0.8

NT= Not Tested OHT= Over Holding Time U=Analyte not detected at the limit specified R= Data rejected B= Analyte detected in blank

RPD(%)= Relative Percent Difference of the Mean [box] = RPD greater than 25%.

Table D–2. Whatcom Dairy #2, Quality Assurance Results.

(Units= mg/L unless shown otherwise)

Sample Event	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Persulfate Nitrogen	Total Phosphorus	Chloride	Total Coliform (CFU/100ml)	Fecal Coliform (CFU/100ml)	TOC Transport Blank	Iron
02/27/91	549	58	50.6	8.9 J	0.09	7.4 J	0.22	59.1	1 U	1 U	0.75	
	548	81	67.1	8.8 J	0.02	7.2 J	0.33	59	1 U	1 U		
RPD=	0.2	33	28.0	1.1	130	2.7	40	0.2	--	--		
05/21/91	472	53	17	31	0.01 J	NT	0.29	40.3	1 U	1 U	1.0 U	
	630	58	16.7	30	0.01 J	NT	0.28	40.5	1 U	1 U		
RPD=	28.7	9.0	1.8	3.3	0.0	--	3.5	0.5	--	--		
08/13/91	212	53	15.7	28	0.02 U	NT	4.7	7.9	5 X	1 U	1.0 U	
	236	48	15	29	0.02 U	NT	4.9	7.7	1 U	1 UX		
RPD=	10.7	9.9	4.6	3.5	--	--	4.2	2.6	--	--		
10/28/91	472	52	22.7	84	0.02	NT	2.2	53.3	1 U	1 X	1.0 U	
	488	42	22.6	83	0.02 U	NT	2.2	50.4	1 U	1 X		
RPD=	3.3	21	0.4	1.2	--	--	0.0	5.6	--	0.0		
04/27/92	328	22	8.4	26	0.01 U	NT	0.872	22.9	1 U	1 U	NT	
	347	19	8.5	26.4		NT	0.881	23.9	1 U	1 U		
RPD=	5.6	15	1.2	1.5	--	--	1.0	4.3	--	--		
07/14/92	497	33.8	9.34	22.8	0.05 U	NT	0.788	45.9	1 U	1 U	NT	5.27
	501	33.8	9.61	23.2	0.05 U	NT	0.717	46.9	1 U	1 U		5.26
RPD=	0.8	0.0	2.8	1.7	--	--	9.4	2.2	--	--		0.2
10/19/92	249	22	6.3	19	0.2 U	NT	1.04	20.2	1 U	1 U		
	234	23	6.9	15.6	0.2 U	NT	0.77	20	1 U	1 U		
RPD=	6.2	4.4	9.1	19.7	--	--	29.8	1.0	--	--		
01/11/93	425	34.4	12.9	23	0.01 U	NT	0.421 J	39.4	1 U	1 U	NT	
	423	33.8	12.9	23	0.01 U	NT	0.415 J	39.6	1 U	1 U		
RPD=	0.5	1.8	0.0	0.0	--	--	1.4	0.5	--	--		
04/26/93	486	46	17.5	79	0.01 U	NT	3.35	42.2	NT	NT	NT	0.885
	465	43.7	18.4	80.2	0.01 U	NT	3.35	42.4	NT	NT		0.87
RPD=	4.4	5.1	5.0	1.5	--	--	0.0	0.5	--	--		1.7

U= Analyte not detected above listed value. J= Estimated value. X= Many background organisms. NT= Not tested.

RPD= Relative percent difference of the mean [boxed] = RPD greater than 25%.

Table D–3. Hornby Dairy, Quality Assurance Results (mg/L).

Sampling Event	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia–N	Nitrate+ Nitrite–N	Total Persulfate Nitrogen	Total Phosphorus as P	Chloride	TOC Transport Blank
4/25/90	NT	NT	36.6	1.2	96	NT	0.15	NT	0.32
	NT	NT	31.5	1.25	93.1	"	0.18	NT	
RPD(%)=	—	—	15.0	4.1	3.1	—	18.2	—	
7/03/90	904	39.9	10.6	0.39	6.61	NT	0.07	10.6	0.3
	823	46.1	10.2	0.32	6.67	"	0.09	10.3	
RPD(%)=	9.4	14.4	3.8	19.7	0.9	—	25.0	2.9	
11/06/90	835	11	58.3	0.021	7.63	NT	0.025	11.4	NT
	823	11	57.8	0.022	7.65	"	0.0265	11	
RPD(%)=	1.4	0.0	0.9	4.7	0.3	—	5.8	3.6	
1/28/91	825	10	18.1	0.008 J	5.8 J	7.32	0.013	11.5	0.4
	814	10	37.7	0.013 J	5.97 J	8.78	0.012	12	
RPD(%)=	1.3	—	70.3	47.6	2.9	18.1	8.0	4.3	
10/25/91	728	11	8.33	0.04 U	9.3	NT	0.15	13.4	4.47
	758	15	7.36	0.04 U	9.3	NT	0.11	13	
RPD(%)=	4.0	30.8	12.4	—	0.0	—	30.8	3.0	
06/09/92	780	23	8	0.187	10.1	NT	0.035	15.6	NT
	776	19	8.5	0.184	10.8	NT	0.039	15.3	
RPD(%)=	0.5	19.0	6.1	1.6	6.7	—	10.8	1.9	
09/14/92	789	17	--	0.103	8.76	NT	0.011	11.8	NT
	761	21	--	0.103	8.65	NT	0.012	11.8	
RPD(%)=	3.6	21.1	—	0.0	1.3	—	8.7	0.0	
12/14/92	787	10 U	5.1	0.05	8	NT	0.036	11.3	NT
	764	10 U	4.9	0.05	7.88	NT	0.037	11	
RPD(%)=	3.0	—	4.0	0.0	1.5	—	2.7	2.7	
03/15/93	722	19.2	5.5	0.045	7.96	NT	0.046	10.8	NT
	738	7.8	5.6	0.048	8.09	NT	0.042	10.8	
RPD(%)=	2.2	84.4	1.8	6.5	1.6	—	9.1	0.0	

NT= Not tested. U= Analyte not detected above specified concentration. J= Estimated concentration.

[box] = RPD greater than 25%.

Table D–4. Sheridan Dairy, Quality Assurance Results.
(Units= mg/L unless shown otherwise.)

Well I	Date	Total Dissolve Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Persulfate Nitrogen	Total Phosphorus	Chloride	Total Coliform (CFU/100 ml)	Fecal Coliform (CFU/100 ml)	TOC Transport Blanks
MW3	06/18/91	334	10 U	1 U	0.031	3.6	3.6	0.13	22.2	3 U	3 U	1 U
Duplicate		333	10 U	1 U	0.033	3.6	3.6	0.13	21.7	3 UX	1 U	
RPD(%)		0.3	--	--	6.3	0.0	0.0	0.0	2.3	--	--	
MW3	09/16/91	380	3.1	1.8 J	0.04 U	2.4	NT	0.45	29	1 U	1 U	0.8
Duplicate		210	8.9	2.0 J	0.04 U	2.4	NT	0.14	29	1 U	1 U	
RPD(%)		58	97	11	--	0.0	--	105	0.0	--	--	
MW2	01/07/92	492	6.0	2.5	0.077	2.93	NT	0.131	45.0	1 U	1 U	1 U
Duplicate		512	7.5	2.5	0.072	2.93	NT	0.129	44.8	1 U	1 U	
RPD(%)		4.0	22	0.0	6.7	0.0	--	1.5	0.4	--	--	
MW3	04/14/92	308	4.8	2.4	0.01 U	4.64	NT	0.118	18.4	1 U	1 U	1 U
Duplicate		306	4.7	1.5	0.01 U	4.75	NT	0.123	19.0	1 U	1 U	
RPD(%)		0.7	2.1	46	--	2.3	--	4.1	3.2	--	--	

U= Analyte not detected above reported concentratio

J= Estimated value.

NT= Not tested.

[ ] = RPD greater than 25%.

RPD= Relative Percent Difference (ratio of the difference and mean of duplicate results expressed as a percentage).

CFU= Colony forming unit.

APPENDIX E

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Table E-1. Whatcom Dairy #1, Field Parameter Results

Site Name	Date	pH	Temperature (°C)	Specific Conductance (umhos/cm)
MW1	02/28/90	6.1	9.8	310
MW1	04/10/90	5.9	11.4	420
MW1	05/16/90	7.1	9.5	258
MW1	06/19/90	5.7	11.5	710
MW1	07/31/90	6.5	13.2	395
MW1	08/27/90		14.5	1060
MW1	09/25/90	6.6	13.7	1110
MW1	10/22/90	6.6	13.6	980
MW1	11/27/90	6.6	11.0	940
MW1	12/18/90	7.1	11.8	940
MW1	01/22/91	6.7	11.0	900
MW1	02/26/91	6.8	11.0	1350
MW1	08/14/91	6.7	12.3	620
MW1	10/29/91	6.6	11.5	550
MW1	04/28/92	6.7	10.5	500
MW1	07/15/92	6.4	12.6	920
MW1	10/20/92	6.6	12.6	630
MW1	01/12/93	6.4	10.8	700
MW1	04/27/93	6.2	10.2	580
MW2	02/28/90	6.0	9.1	342
MW2	04/10/90	5.9	9.2	675
MW2	05/16/90	6.9	7.6	292
MW2	06/19/90	6.2	12.6	650
MW2	08/01/90	6.2	14.3	1100
MW2	08/27/90		14.9	1510
MW2	09/25/90	6.4	14.1	1370
MW2	10/22/90	6.5	13.5	1290
MW2	11/27/90	6.7	11.9	1280
MW2	12/18/90	7.1	11.6	1360
MW2	01/22/91	7.0	11.5	1000
MW2	02/26/91	6.9	11.8	1440
MW2	08/14/91		11.7	1520
MW2	10/29/91	6.8	11.9	1050
MW2	04/28/92	7.1	10.8	910
MW2	07/15/92	6.7	13.2	1080
MW2	10/20/92	6.9		
MW2	10/20/92		13.4	1040
MW2	01/12/93	6.9	11.6	840
MW2	04/27/93	7.0	10.0	690
MW3	02/28/90	5.6	8.9	227
MW3	04/10/90	5.7	9.4	650
MW3	05/16/90	7.1	7.8	228
MW3	06/19/90	6.0	10.4	650

Table E-1 Continued.

Site Name	Date	pH	Temperature (°C)	Specific Conductance (umhos/cm)
MW3	08/01/90	6.4	13.0	930
MW3	08/27/90		14.8	930
MW3	09/25/90	6.5	14.1	1210
MW3	10/22/90	6.6	13.8	820
MW3	11/27/90	6.3	13.8	680
MW3	12/18/90	6.8	12.3	820
MW3	01/22/91	6.5	12.5	1700
MW3	02/26/91	6.9	12.0	940
MW3	08/14/91	6.8	11.3	1000
MW3	10/29/91	6.8	12.2	750
MW3	04/28/92	7.0	10.5	720
MW3	07/15/92	6.7	13.6	1210
MW3	10/20/92	7.0	13.8	1200
MW3	01/12/93	6.8	12.3	720
MW3	04/27/93	6.7	10.1	900
MW4	02/28/90	6.2	8.6	162
MW4	03/07/90	6.4	6.8	220
MW4	04/10/90	6.1	10.3	290
MW4	05/16/90	7.1	11.3	285
MW4	06/19/90	6.2	13.4	251
MW4	07/31/90	6.4	13.5	242
MW4	08/27/90		15.0	400
MW4	09/25/90	5.9	13.6	490
MW4	10/22/90	5.7	12.5	477
MW4	11/27/90	6.2	11.0	620
MW4	12/18/90	6.6	9.3	490
MW4	01/22/91	6.2	6.8	345
MW4	02/26/91	6.2	8.1	458
MW4	08/14/91	6.6	13.3	1240
MW4	10/29/91	6.5	12.7	1250
MW4	04/28/92	6.6	9.7	1020
MW4	07/15/92	6.0	13.7	1300
MW4	10/20/92	6.7	13.5	1380
MW4	01/12/93	6.6	9.6	1100
MW4	04/27/93	6.6	8.8	1190
MW5	02/28/90	6.0	9.0	202
MW5	03/07/90	6.3	7.0	220
MW5	04/10/90	6.1	9.2	248
MW5	05/16/90	7.1	8.6	210
MW5	06/19/90	6.1	11.2	175
MW5	07/31/90	6.3	12.1	140
MW5	10/22/90	6.7	12.7	172
MW5	11/27/90	6.7	10.0	480
MW5	12/18/90	6.3	8.5	920
MW5	01/22/91	8.9	7.6	700

Table E-1 Continued.

Site Name	Date	pH	Temperature (°C)	Specific Conductance (umhos/cm)
MW5	02/26/91	5.9	8.2	354
MW5	08/14/91	6.0	12.6	252
MW5	10/29/91	6.0	9.6	240
MW5	04/28/92	6.3	9.1	338
MW5	07/15/92	5.8	12.5	410
MW5	10/20/92		13.4	590
MW5	01/12/93	6.1	8.2	580
MW5	04/27/93	5.9	8.3	620
MW6	02/28/90	6.7	10.5	1000
MW6	03/07/90	7.0	7.5	1000
MW6	04/10/90	6.6	9.1	1000
MW6A	08/01/90	6.3	12.9	
MW6A	11/27/90	6.5	11.8	1230
MW6A	12/18/90	7.2	8.1	1230
MW6A	01/22/91	7.0	11.5	1100
MW6A	02/26/91	6.9	12.2	1000
MW6A	08/14/91	6.8	12.6	1420
MW6A	10/29/91	7.0	11.6	1980
MW6A	04/28/92	7.2	11.7	1220
MW6A	07/15/92	6.7	14.3	1250
MW6A	10/20/92	6.8	12.8	2140
MW6A	01/12/93	6.7	10.8	2000
MW6A	04/27/93	6.7	11.2	1400
MW7A	12/18/90	7.1	8.4	770
MW7A	01/22/91	6.5	11.5	700
MW7A	02/26/91	6.5	11.8	800
MW7A	08/14/91	6.6	12.1	680
MW7A	10/29/91	6.7	10.9	1300
MW7A	04/28/92	6.9	11.0	520
MW7A	07/15/92	6.1	14.0	730
MW7A	10/20/92	6.7	12.8	840
MW7A	01/12/93	6.6	10.5	700
MW7A	04/27/93	6.7	10.9	435
MW8	07/15/92	5.6	12.6	282
MW8	10/20/92	6.2	11.7	240
MW8	01/12/93	5.9	8.4	230
MW8	04/26/93	5.9	10.4	248
Lagoon 1	07/31/90	7.1	25.7	4480
Lagoon 1	08/14/91	7.7	22.4	7700
Lagoon 1	10/29/91	7.9	5.4	3790
Lagoon 1	04/28/92	8.0	14.9	6100
Lagoon 1	07/15/92	7.3	24.9	

Table E-2. Whatcom Dairy #2, Field Parameter Results.

Site Name	Date	pH (Std Units)	Temperature (°C)	Sp. Cond. (umhos/cm)
MW1 (Upgradient)	02/27/91	6.2	9.4	290
MW1 (Upgradient)	05/21/91	6.4	9.1	192
MW1 (Upgradient)	08/31/91	6.3	11.7	257
MW1 (Upgradient)	10/28/91	6.3	10.6	215
MW5 (Upgradient)	07/14/92	5.9	12.4	180
MW5 (Upgradient)	10/19/92	6.4	12.3	188
MW5 (Upgradient)	01/11/93	6.3	9.7	174
MW5 (Upgradient)	04/26/93	6.2	8.6	170
MW2	02/27/91	6.9	10.9	370
MW2	05/21/91	7.0	9.6	620
MW2	08/31/91	7.0	12.1	1010
MW2	10/28/91	6.9	10.6	970
MW2	04/27/92	6.5	10.7	252
MW2	07/14/92	6.9	12.5	342
MW2	10/19/92	6.7	12.0	422
MW2	01/11/93	6.4	10.4	580
MW2	04/26/93	6.8	9.7	222
MW3	02/27/91	6.9	11.8	900
MW3	05/21/91	7.0	9.8	840
MW3	08/31/91	7.3	11.7	760
MW3	10/28/91	7.0	11.3	790
MW3	04/27/92	6.8	10.4	480
MW3	07/14/92	6.7	12.5	710
MW3	10/19/92	7.0	12.0	740
MW3	01/11/93	6.8	11.4	550
MW3	04/26/93	7.1	9.6	810
MW4	02/27/91	6.8	11.8	700
MW4	05/21/91	7.5	9.8	2080
MW4	08/31/91	7.7	12.1	314
MW4	10/28/91	6.9	10.9	460
MW4	04/27/92	7.0	11.0	462
MW4	07/14/92	6.9	13.4	307
MW4	10/19/92	6.7	12.2	260
MW4	01/11/93	6.6	11.5	700
MW4	04/26/93	7.2	10.1	265
MW6	07/14/92	7.0	13.3	780
MW6	10/19/92	7.0	12.3	605
MW6	01/11/93	7.1	10.4	510
MW6	04/26/93	7.1	9.2	419
LAGOON BERM	08/31/91	7.6	23.8	6800
LAGOON BERM	10/28/91	7.4	6.4	8000
LAGOON BERM	07/14/92	7.4	23.5	1720
LAGOON BERM	10/19/92	7.7	12.4	7000
LAGOON BERM	04/26/93	NT	NT	8500

Table E–3. Hornby Dairy, Field Parameter Results.

Site Name	Date	pH (Std.Units)	Temperature (°C)	Specific Conductance (umhos/cm)
MW1	04/25/90	7.9	11.0	NT
MW1	07/03/90	8.0	13.7	950
MW1	11/06/90	8.6	14.4	920
MW1	01/28/91	8.7	9.0	800
MW1	10/25/91	7.6	13.8	900
MW1	06/08/92	6.8	17.4	1010
MW1	09/14/92	NT	15.0	950
MW1	12/14/92	7.3	10.8	800
MW1	03/15/93	7.8	13.6	880
MW2	04/25/90	7.4	12.3	NT
MW2	07/03/90	7.9	16.1	1250
MW2	11/07/90	7.7	14.3	1520
MW2	01/29/91	7.2	10.0	1100
MW2	10/25/91	7.1	14.2	1200
MW2	06/08/92	5.4	19.1	1560
MW2	09/15/92	NT	13.6	1620
MW2	12/15/92	7.0	13.3	1770
MW2	03/16/93	6.8	10.9	1610
MW3	04/25/90	8.3	12.8	NT
MW3	07/03/90	8.5	14.9	800
MW3	11/07/90	9.6	14.0	970
MW3	01/29/91	9.5	8.7	600
MW3	10/25/91	7.4	13.1	1210
MW3	06/09/92	7.5	16.1	1390
MW3	09/15/92	NT	14.2	1510
MW3	12/14/92	6.9	11.4	1380
MW3	03/15/93	7.5	12.1	1430
MW4	04/25/90	7.7	12.1	NT
MW4	07/03/90	8.9	15.4	670
MW4	11/07/90	8.2	14.0	1150
MW4	01/29/91	8.2	9.8	640
MW4	10/25/91	7.4	14.0	1210
MW4	06/08/92	5.8	17.6	1150
MW4	09/15/92	NT	13.0	1740
MW4	12/15/92	7.1	11.7	1560
MW4	03/16/93	6.9	9.5	1300
MW5	04/25/90	8.0	12.1	NT
MW5	07/03/90	9.6	15.0	850
MW5	11/07/90	9.6	14.7	920
MW5	01/29/91	8.6	8.5	630
MW5	10/25/91	7.5	14.0	1110
MW5	06/08/92	7.1	15.8	940
MW5	09/15/92	NT	12.9	1270

Table E-3 Continued.

Site Name	Date	pH (Std.Units)	Temperature (°C)	Specific Conductance (umhos/cm)
MW5	12/15/92	7.3	12.4	1250
MW5	03/16/93	7.1	10.0	1210
SETTLING POND #1	04/25/90	6.8	18.9	NT
SETTLING POND #1	10/25/91	7.7	11.5	1680
SETTLING POND #1	12/15/92	7.7	9.5	1820
SETTLING POND #2	01/29/91	7.6	6.7	1710
MAIN LAGOON	04/25/90	7.4	17.4	NT
MAIN LAGOON	07/03/90	7.6	27.7	2250
MAIN LAGOON	11/07/90	7.7	7.8	1600
MAIN LAGOON	09/15/92	NT	14.5	1700
MAIN LAGOON	03/15/93	7.5	10.2	1500
DAVIS	11/07/90	7.8	14.0	570
DAVIS	01/29/91	7.9	12.5	468
DAVIS	10/25/91	7.8	13.9	483
DAVIS	09/14/92	NT	14.0	510
DAVIS	12/14/92	7.6	11.9	438
DAVIS	03/15/93	8.1	14.1	460

NT= Not tested.

Table E–4. Sheridan Dairy, Field Parameter Results.

Site Name	Date	pH (Std Units)	Temperature (°C)	Specific Conductance (micromhos/cm)
Lagoon	09/16/91	NT	22	7000
Lagoon	01/07/92	7.4	NT	NT
MW1	06/18/91	7.3	12.5	400
MW1	09/16/91	NT	13.8	535
MW1	01/07/92	7.0	11.1	500
MW1	04/14/92	7.0	11.7	403
MW2	06/18/91	6.6	14.1	550
MW2	09/16/91	NT	15.5	720
MW2	01/07/92	6.6	11.3	660
MW2	04/14/92	6.6	12.6	505
MW3	06/18/91	6.9	13.9	382
MW3	09/16/91	NT	13.8	595
MW3	01/07/92	6.7	11.4	490
MW3	04/14/92	6.7	12.5	360
MW4	06/18/91	6.6	13.9	710
MW4	09/16/91	NT	15.3	720
MW4	01/07/92	6.5	11.5	910
MW4	04/14/92	6.6	12.6	700

NT= Not tested.

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APPENDIX F

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Table F–1. Whatcom Dairy #1, Water Quality Results February 1990 to April 1993. (Units = mg/L).

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia–N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
Lagoon 1	158027	04/10/90	2890	4400	1630	275	0.06	26	139
Lagoon 1	318025	07/31/90	4120 J	7070	2280	322	0.08	89 J	145
Lagoon 1	438047	10/22/90	3770	1300	1620	275	0.61	71.5	148
Lagoon 1	048059	01/22/91	3530	3100	1310	508	1.3 J	35.4	146
Lagoon 1	338174	08/14/91	NT	6170	1390	589	1.2	83	225
Lagoon 1	448096	10/29/91	NT	3400	974	500	0.62	49	188
Lagoon 1	188119	04/28/92	NT	7800	2100	600 J	0.67 J	80.4	285
Lagoon 1	298146	07/15/92	NT	NT	NT	NT	NT	NT	315
Lagoon 1	188171	04/27/93	6850	14600	2880	582	0.45 J	133	399
MW1	098060	02/28/90	411	10	13.8	0.05	8.5	0.12	5.8
MW1	158021	04/10/90	226	6.8	29.6	0.05	7.6	0.01	8.1
MW1	208072	05/16/90	201	12.4	6.1	0.04	2.2	0.09	13.8
MW1	258031	06/19/90	680	449	95	0.01	0.01	0.04	51.2
MW1	318024	07/31/90	318	88	38.4	0.01 U	0.01 U	0.05 J	24.9
MW1	358073	08/27/90	1040	578	225	0.02	0.11	0.16	84.8
MW1	398032	09/25/90	980	650	244	2.8	0.05	0.12	
MW1	438044	10/22/90	864	255	175	11	0.10	0.26	60.8
MW1	488034	11/27/90	710	160	61.1	7.5	0.01 U	0.02	67.4
MW1	518064	12/18/90	505	120	42.3	9.7	0.2 J	0.1	40.3
MW1	048055	01/22/91	613	120	202	31	0.04 J	0.12	52.5
MW1	098044	02/26/91	941	260	140	52	0.10	0.03	80.2
MW1	338170	08/14/91	333	52	18.5	45	0.02 U	0.08	34.3
MW1	448092	10/29/91	353	33	11.7	30	0.02 U	0.02	46.4
MW1	188114	04/28/92	407	67	23.9	13	0.01 U	0.018	32.4
MW1	298142	07/15/92	516	140	27.0	50	0.05 U	0.17	57.1
MW1	438091	10/20/92	344	52	15.6	26	0.3	0.1	35.9
MW1	038116	01/12/93	520	5 U	3.0	32	54	0.021 J	34.5
MW1	188167	04/27/93	537	14.3	5.4	18	47	0.014	32.0
MW2	098061	02/28/90	245	8.4	26.7	0.05	16	0.01	10.8

Table F-1 Continued.

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
MW2	158022	04/10/90	413	10	2.3 B	0.2	38	0.01	14.8
MW2	208073	05/16/90	196	76	28.6	0.02	1.4	0.06	19.6
MW2	258032	06/19/90	495	196	38.5	0.01	0.18	0.1	48.4
MW2	318028	08/01/90	1110	533	236	0.09	0.01 U	0.06 J	87.6
MW2	358074	08/27/90	1640	1064	429	1.8	0.01 U	0.13	111
MW2	398033	09/25/90	1300	800	304	7.6	0.02	0.14	
MW2	438045	10/22/90	1200	120	217	8.4	0.01 U	0.27	89.8
MW2	488035	11/27/90	1140	240	93.1	31	0.01 U	0.06	72.9
MW2	518065	12/18/90	1060	300	100	59	0.16 J	0.28	81.3
MW2	048056	01/22/91	536	120	84.5	71	0.04 J	0.16	35.7
MW2	098045	02/26/91	822	1760	88.7	102	0.14	0.14	77.3
MW2	338171	08/14/91	856	240	69.2	142	0.02 U	0.23	79.0
MW2	448093	10/29/91	616	140	55.8	130	0.02 U	0.12	52.1
MW2	188115	04/28/92	548	93	39.8	58	0.011	0.138	44.6
MW2	298143	07/15/92	640	106	31.9	64	0.05 U	0.17	52.7
MW2	438092	10/20/92	515	110	37.4	56	0.2 U	0.19	42.8
MW2	038117	01/12/93	481	83	31.0	68	0.015	0.097 J	42.3
MW2	188168	04/27/93	372	62	21.5	62	0.01 U	0.092	43.9
MW3	098062	02/28/90	184	10	18.3	0.03	14	0.01	16.0
MW3	158023	04/10/90	381	12	2.8 B	0.2	43	0.01 U	16.4
MW3	208074	05/16/90	196	7.7	4.6	0.02	0.68	0.08	12.9
MW3	258033	06/19/90	540	189	46.1	0.01	0.1	0.1	56.5
MW3	318026	08/01/90	730	340	133	0.02	0.01 U	0.03 J	54.1
MW3	358075	08/27/90	911	436	201	0.31	0.01 U	0.14	67.4
MW3	398034	09/25/90	865	365	169	24	0.02	0.12	
MW3	438046	10/22/90	525	35	77.4	30	0.01 U	0.28	54.1
MW3	488036	11/27/90	460 J	47	26.3	16	0.01 U	0.01	58.3
MW3	518066	12/18/90	592	140	48.2	14	0.17 J	0.11	78.1
MW3	048057	01/22/91	1240	170	214	74	0.04 J	0.17	121
MW3	098046	02/26/91	592	130	60.4	53	0.11	0.08	44.4
MW3	338172	08/14/91	622	120	47.0	42	0.02 U	0.12	51.9

Table F-1 Continued.

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
MW3	448094	10/29/91	531	80	32.8	54	0.02 U	0.07	34.2
MW3	188116	04/28/92	514	86	38.1	37	0.01 U	0.112	38.0
MW3	298144	07/15/92	802	146	45.9	56	0.05 U	0.248	66.7
MW3	438093	10/20/92	569	150	54.9	88	0.2 U	0.33	48.6
MW3	038118	01/12/93	396	61	22.7	50	0.01 U	0.034 J	41.0
MW3	188169	04/27/93	564	112	38.7	55	0.01 U	0.121	67.9
MW4	098063	02/28/90	140	8.1	7.1	0.02	6.0	0.02	2.2
MW4	108016	03/07/90	137	7.5	6.6	0.03	8.3	0.01 U	3.9
MW4	158025	04/10/90	149	7.1	3.0 B	0.02	4.7	0.01 U	3.8
MW4	208075	05/16/90	207	6.7	9.7	0.06	2.9	0.02	12.9
MW4	258034	06/19/90	176	5.1	0.50 U	0.05	2.5	0.01	14.3
MW4	318022	07/31/90	183	13	8.7	0.07	0.48	0.01 J	20.2
MW4	358071	08/27/90	323	11	17.9	0.13	0.01 U	0.05	42.9
MW4	398030	09/25/90	390	19	18.8	0.13	0.23	0.04	
MW4	438042	10/22/90	417	22	70.0	0.23	0.01 U	0.25	69.7
MW4	488032	11/27/90	390	29	40.0	0.12	2.0	0.03	56.6
MW4	518062	12/18/90	311	38	7.9	0.22	12 J	0.03	13.6
MW4	048052	01/22/91	384	10 U	26.0	0.21	25 J	0.005 U	14.1
MW4	098042	02/26/91	474	10 U	22.1	0.15	0.23	0.02	21.4
MW4	338167	08/14/91	856	114	44.4	0.55	0.12	0.06	88.6
MW4	448089	10/29/91	934	145	54.0	77	0.02	0.04	96.6
MW4	188112	04/28/92	836	92	39.5	43	0.01	0.04	61.1
MW4	298139	07/15/92	726	108	29.7	82	0.051	0.064	64.5
MW4	438088	10/20/92	721	115	44.0	83	0.02 U	0.07	66.4
MW4	038113	01/12/93	638	93	42.8	79	0.44	0.028 J	47.3
MW4	188164	04/27/93	840	114	44.4	78	0.01 U	0.036	60.6
MW5	098066	02/28/90	159	6.2	6.5	0.02	7.7	0.05	4.3
MW5	108015	03/07/90	141	8.2	4.7	3.6	7.0	0.03	3.8
MW5	158020	04/10/90	138	9.3	8.4	0.06	5.9	0.01 U	3.3
MW5	208071	05/16/90	135	11	8.3	0.03	3.7	0.01	11.1
MW5	258030	06/19/90	150	15	0.50 U	0.01	2.5	0.005 U	1.8

Table F-1 Continued.

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
MW5	318020	07/31/90	156	16	5.6	0.02	3.2	0.01 J	2.4
MW5	438041	10/22/90	155	5 U	6.8	0.07	2.5	0.31	2.4
MW5	488031	11/27/90	384	10 U	1.5 B	0.02	42	0.01 U	9.3
MW5	518061	12/18/90	675	24	2.0 B	0.005 U	80 J	0.005 U	33.6
MW5	048051	01/22/91	744	10 U	4.0 B	0.05 U	99 J	0.005 U	46.7
MW5	098041	02/26/91	385	10 U	4.7	0.012	43	0.011	22.9
MW5	338166	08/14/91	227	0.1 U	2.0	0.04 U	17	0.01 U	14.6
MW5	448088	10/29/91	237	5.2	2.0	0.04 U	18	0.01 U	19.4
MW5	188111	04/28/92	370	3 U	1.4	0.011	38	0.01 U	15.0
MW5	298138	07/15/92	408	5 U	1.6	0.08 U	29	0.05	20.9
MW5	438087	10/20/92	592	5	1.3	0.5	46	0.02 U	26.4
MW5	038112	01/12/93	601	5 U	1.3	0.011	75	0.01 U	35.6
MW5	188163	04/27/93	851	5 U	1.7	0.012	91	0.01 U	52.0
MW6	098065	02/28/90	781	103	93	29	0.01 U	0.01	49.0
MW6	108018	03/07/90	937	135	112	33	0.02	0.01	54.8
MW6	158026	04/10/90	645	80	26.6	14	0.01 U	0.01	37.5
MW6A	318028	08/01/90	1340	870	359	89.7	0.01 U	0.09 J	88.6
MW6A	488037	11/27/90	775	47	86.9	69	0.04	0.01 U	88.9
MW6A	518067	12/18/90	803	270	71.8	91	0.21 J	0.2	68.9
MW6A	048058	01/22/91	547	79	56.7	81	0.03 J	0.08	47.1
MW6A	098047	02/26/91	580	88	31.6	46	0.01	0.02	50.4
MW6A	338173	08/14/91	816	120	43.6	101	0.02 U	0.12	67.7
MW6A	448095	10/29/91	1130	190	68.7	160	0.02 U	0.03	105
MW6A	188118	04/28/92	701	110	48.0	103	0.01 U	0.041	60.3
MW6A	298145	07/15/92	732	111	35.7	74	0.05 U	0.046	72.8
MW6A	438094	10/20/92	1160	300	84.4	184	0.2 U	0.15	102
MW6A	038119	01/12/93	1080	239	82.6	157	0.01 U	0.053 J	94.2
MW6A	188170	04/27/93	783	124	49.2	108	0.01 U	0.023	72.7
MW7A	518068	12/18/90	486	64	19.3	0.06	0.08 J	0.17	45.2
MW7A	048054	01/22/91	627	29	151	0.02	0.03 J	0.05	60.2
MW7A	098043	02/26/91	636	56	67.0	0.016	0.01 U	0.017	72.0

Table F-1 Continued.

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
MW7A	338169	08/14/91	484	53	20.8	4.2	0.02 U	0.01	40.5
MW7A	448091	10/29/91	949	160	52.6	23	0.02 U	0.04	84.5
MW7A	188113	04/28/92	441	40	16.5	17	0.01 U	0.034	30.3
MW7A	298140	07/15/92	530	54	14.1	15	0.05 U	0.046	36.2
MW7A	438090	10/20/92	642	67	21.7	4.1	12	0.05	46.2
MW7A	038115	01/12/93	530	46	18.0	14	0.01 U	0.012 J	41.4
MW7A	188165	04/27/93	410	22	8.4	6.8	0.01 U	0.019	27.4
MW8	298137	07/15/92	275	5 U	1.6	0.39	0.05 U	0.082	18.8
MW8	438096	10/20/92	237	14	1.5	6.1	0.2 U	0.03	16.9
MW8	038111	01/12/93	254	5 U	1.2	0.29	0.01 U	0.01 U	17.6
MW8	188162	04/26/93	220	5 U	1.4	0.25	0.01 U	0.01 U	18.1

J= Estimated value.
U= Analyte not detected above value listed.
B= Analyte detected in blank.

Table F–2. Whatcom Dairy #1, Bacteriologic and Miscellaneous Water Quality Results.
(Units= mg/L unless shown otherwise.)

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron, Dissolved	Iron, Total Recoverable	Total Persulfate Nitrogen	Total Solids	Total Suspended Solids
Lagoon 1	158027	04/10/90	440000	230000					575
Lagoon 1	318025	07/31/90	7400000 J	1000000 J					925
Lagoon 1	438047	10/22/90	8600000	5800000					
Lagoon 1	048059	01/22/91	3300000	2100000			0.01 U		1590
Lagoon 1	338174	08/14/91	230000	200000					
Lagoon 1	188119	04/28/92	2100000 S	1200000				8220	
Lagoon 1	298146	07/15/92	NT	NT		3.5		20900	
Lagoon 1	188171	04/27/93	NT	NT				11800	
MW1	098060	02/28/90	3 U	3 U					
MW1	158021	04/10/90	1 U	1 U					
MW1	208072	05/16/90	1	1 U					
MW1	258031	06/19/90	1 U	1 U					
MW1	318024	07/31/90	1 U	1 U					
MW1	358073	08/27/90	3 U	3 U					
MW1	398032	09/25/90	1 U	1 U					
MW1	438044	10/22/90	1 U	1 U					
MW1	488034	11/27/90	1 U	1 U			10.3		
MW1	518064	12/18/90	H	H			3.6		
MW1	048055	01/22/91	1 U	1 U			11.4		
MW1	098044	02/26/91	1 U	1 U			3.7		
MW1	338170	08/14/91	1 U	1 U					
MW1	448092	10/29/91	1 U	1 U					
MW1	188114	04/28/92	1 U	1 U					
MW1	298142	07/15/92	2	1 U		58.1			
MW1	438091	10/20/92	1 U	1 U					
MW1	038116	01/12/93	1 U	1 U					
MW2	098061	02/28/90	3 U	3 U					
MW2	158022	04/10/90	1 U	1 U					

Table F-2 Continued.

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron Dissolved	Iron, Total Recoverable	Total Persulfate Nitrogen	Total Solids	Total Suspended Solids
MW2	208073	05/16/90	3 U	3 U					
MW2	258032	06/19/90	3 U	3 U					
MW2	318026	08/01/90	3 U	3 U					
MW2	358074	08/27/90	3 U	3 U					
MW2	398033	09/25/90	1 U	1 U					
MW2	438045	10/22/90	1 U	1 U					
MW2	488035	11/27/90	1 UX	1 U			31.8		
MW2	518065	12/18/90	H	H			13.9		
MW2	048056	01/22/91	148 J	7 J			20.6		
MW2	098045	02/26/91	1 U	1 U			18.0		
MW2	338171	08/14/91	1	1 U					
MW2	448093	10/29/91	5 X	1 U					
MW2	188115	04/28/92	1 UX	1 U					
MW2	298143	07/15/92	1 UX	1 U		15.7			
MW2	438092	10/20/92	1 U	1 U					
MW2	038117	01/12/93	1 U	1 U					
MW3	098062	02/28/90	3 U	3 U					
MW3	158023	04/10/90	1 U	1 U					
MW3	208074	05/16/90	3 U	3 U					
MW3	258033	06/19/90	3 U	3 U					
MW3	318027	08/01/90	3 U	3 U					
MW3	358075	08/27/90	3 U	3 U					
MW3	398034	09/25/90	1 U	1 U					
MW3	438046	10/22/90	1 U	1 U					
MW3	488036	11/27/90	1 U	1 U			15.9		
MW3	518066	12/18/90	H	H			7.3		
MW3	048057	01/22/91	3 U	3 U			0.01 U		
MW3	098046	02/26/91	1 UX	1 U			12.9		
MW3	338172	08/14/91	1 U	1 U					
MW3	448094	10/29/91	1 U	1 U					
MW3	188116	04/28/92	1 UX	1 UX					

Table F-2 Continued.

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron Dissolved	Iron, Total Recoverable	Total Persulfate Nitrogen	Total Solids	Total Suspended Solids
MW3	298144	07/15/92	1 UX	1 U		35.4			
MW3	438093	10/20/92	1 U	1 U					
MW3	038118	01/12/93	1 U	1 U					
MW3	188169	04/27/93	NT	NT	20.6				
MW4	098063	02/28/90	3 U	3 U					
MW4	108016	03/07/90	1 U	1 U					
MW4	158025	04/10/90	1 U	1 U					
MW4	208075	05/16/90	1 U	1 U					
MW4	258034	06/19/90	1 U	1 U					
MW4	318022	07/31/90	1 U	1 U					
MW4	358071	08/27/90	1 U	1 U					
MW4	398030	09/25/90	1 U	1 U					
MW4	438042	10/22/90	1 U	1 U					
MW4	488032	11/27/90	1 UX	1 U			2.8		
MW4	518062	12/18/90	H	H			11.1		
MW4	048052	01/22/91	1 U	1 U			27		
MW4	098042	02/26/91	1 U	1 U			0.62		
MW4	338167	08/14/91	1 U	1 U					
MW4	448089	10/29/91	1 U	1 U					
MW4	188112	04/28/92	1 U	1 U					
MW4	298139	07/15/92	1 U	1 U		3.2			
MW4	438088	10/20/92	1 U	1 U					
MW4	038113	01/12/93	1 U	1 U					
MW5	108015	03/07/90	1 U	1 U					
MW5	158020	04/10/90	1 U	1 U					
MW5	208071	05/16/90	1 U	1 U					
MW5	258030	06/19/90	2	1 U					
MW5	318020	07/31/90	1 U	1 U					
MW5	438041	10/22/90	1 U	1 U					
MW5	488031	11/27/90	1 U	1 U			41		
MW5	518061	12/18/90	H	H			89		

Table F-2 Continued.

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron Dissolved	Iron, Total Recoverable	Total Persulfate Nitrogen	Total Solids	Total Suspended Solids
MW5	048051	01/22/91	1 U	1 U			175		
MW5	098041	02/26/91	1 U	1 U			42		
MW5	338166	08/14/91	1 U	1 U					
MW5	448088	10/29/91	1 U	1 U					
MW5	188111	04/28/92	1 U	1 U					
MW5	298138	07/15/92	1 U	1 U		0.27			
MW5	438087	10/20/92	1 U	1 U					
MW5	038112	01/12/93	1 U	1 U					
MW5	188163	04/27/93	NT	NT	0.088				
MW6	098065	02/28/90	3 U	3 U					
MW6	158026	04/10/90	1 U	1 U					
MW6A	318028	08/01/90	3 U	3 U					
MW6A	488037	11/27/90	1 UX	1 U			69		
MW6A	518067	12/18/90	H	H			17		
MW6A	048058	01/22/91	3 U	3 U			23		
MW6A	098047	02/26/91	1 U	1 U			17		
MW6A	338173	08/14/91	1 U	1 U					
MW6A	448095	10/29/91	1 U	1 U					
MW6A	188118	04/28/92	1 U	1 U					
MW6A	298145	07/15/92	1 U	1 U		36.5			
MW6A	438094	10/20/92	1 U	1 U					
MW6A	038119	01/12/93	1 U	1 U					
MW7A	048054	01/22/91	1 U	1 U			0.13		
MW7A	098043	02/26/91	1 U	1 U			2.2		
MW7A	338169	08/14/91	1 U	1 U					
MW7A	448091	10/29/91	1 U	1 U					
MW7A	188113	04/28/92	1 U	1 U					
MW7A	298140	07/15/92	1 U	1 U		249			
MW7A	438090	10/20/92	1 U	1 U					
MW7A	038115	01/12/93	1 U	1 U					
MW7A	188165	04/27/93	NT	NT	12.6				

Table F-2 Continued.

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron Dissolved	Iron, Total Recoverable	Total Persulfate Nitrogen	Total Solids	Total Suspended Solids
MW8	298137	07/15/92	1 U	1 U		6.1			
MW8	438096	10/20/92	1 U	1 U					
MW8	038111	01/12/93	1 U	1 U					

U= Analyte not detected above listed value.
X= Many background organisms.
S= Spreader.
NT= Not Tested.
CFU= Colony forming unit.

Table F-3. Whatcom Dairy #2, Water Quality Results (Units = mg/L).

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
LAGOON	098056	02/27/91	NT	540	3920	672 J	3.8	21	625
LAGOON	218056	05/21/91	NT	4200	5110	810	0.51	1900	645
LAGOON	338161	08/13/91	NT	3700	1180	400	0.24	46	342
LAGOON	448086	10/28/91	NT	21000	2230 J	1000	0.02 U	160	NT
LAGOON	188110	04/27/92	38900	46000	9430 J	1100 J	0.18 J	509 J	962
LAGOON	298136	07/14/92	7760	689	382	407	0.05 U	641	404
LAGOON	438086	10/19/92	NT	6400	1300	790	2.9	94	438
LAGOON	188161	04/26/93	9640	31700	7820 J	830	0.44 J	268	621
MW1	098051	02/27/91	307	10 U	8.7	0.23 J	0.01 U	0.09	6.5
MW1	218051	05/21/91	289	11	3.1	0.22	0.01 UJ	0.09	6.7
MW1	338156	08/13/91	287	7.2	1.7	0.21	0.02 U	0.01 U	4.0
MW1	448081	10/28/91	299	4.2	1.2	0.26	0.02 U	0.03	6.7
MW5	298130	07/14/92	233	8.4	1.0	0.12	0.05 U	0.10	6.6
MW5	438080	10/19/92	396	5	1.7	0.20	0.20 U	0.04	5.7
MW5	038105	01/11/93	186	5 U	1.4	0.17	0.01 U	0.01 J	5.4
MW5	188155	04/26/93	183	6.9	1.5	0.16	0.01 U	0.02	6.5
MW2	098052	02/27/91	225	10 U	15	21 J	0.01 U	0.30	14
MW2	218052	05/21/91	551	56	17	31	0.01 UJ	0.28	40
MW2	338157	08/13/91	661	63	25	53	0.02 U	1.7	76
MW2	448082	10/28/91	684	78	26	110	0.02 U	0.80	61
MW2	188106	04/27/92	207	6.8	2.5	14	0.01 U	0.22	6.1
MW2	298132	07/14/92	345	25	6.1	6.9	0.05 U	0.34	8.4
MW2	438082	10/19/92	242	22	6.6	17	0.20 U	0.90	20
MW2	038107	01/11/93	424	34	13	23	0.01 U	0.42 J	40
MW2	188157	04/26/93	231	9.3	3.2	3.5	0.01 U	0.04	7.9
MW3	098053	02/27/91	492	44	54	64 J	0.07	2.3	51
MW3	218054	05/21/91	553	88	40	53	0.01 UJ	1.9	54
MW3	338158	08/13/91	565	56	21	70	0.02 U	3.0	44
MW3	448083	10/28/91	480	47	23	84	0.02 U	2.2	52

Table F-3 Continued.

Site Name	ID #	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite as N	Total Phosphorus	Chloride
MW3	188107	04/27/92	328	22	8.4	26	0.01 U	0.87	23
MW3	298133	07/14/92	497	34	9.3	23	0.05 U	0.79	46
MW3	438084	10/19/92	418	43	15	24	0.20 U	1.5	37
MW3	038109	01/11/93	328	38	11	34	0.01 U	3.3 J	22
MW3	188158	04/26/93	476	42	18	80	0.01 U	3.4	42
MW4	098054	02/27/91	548	70	59	8.7 J	0.06	0.27	59
MW4	218055	05/21/91	1420	940	241	180	0.15 J	20	145
MW4	338159	08/13/91	224	51	15	29	0.02 U	4.8	7.8
MW4	448085	10/28/91	252	38	10	62	0.02 U	0.86	18
MW4	188109	04/27/92	264	27	8.4	32	0.01 U	1.6	18
MW4	298135	07/14/92	251	12	2.4	14	0.05 U	0.50	9.6
MW4	438085	10/19/92	193	15	3.2	19	0.20 U	0.43	6.8
MW4	038110	01/11/93	498	49	17	20	0.01 U	0.27 J	43
MW4	188160	04/26/93	220	10	6.1	7.4	0.01 U	2.0	8.7
MW6	298131	07/14/92	521	80	17	60	0.05 U	4.2	36
MW6	438081	10/19/92	423	60	19	19	0.20 U	2.9	29
MW6	038106	01/11/93	324	58	18	33	0.01 U	6.4 J	20
MW6	188156	04/26/93	285	38	11	33	0.01 U	5.3	25

J= Estimated value.
U= Analyte not detected above listed value.
NT= Not tested.

Table F-4. Whatcom Dairy #2, Bacteriologic and Miscellaneous Results.
(Units= mg/L unless shown otherwise.)

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron, Dissolved	Iron, Total Recover.	Total Persulfate Nitrogen	Total Solids
LAGOON	098056	02/27/91	1,200,000	700,000			2.1 J	11600
LAGOON	218056	05/21/91	1,500,000	1,400,000				22000
LAGOON	338161	08/13/91	460,000	200,000				5770
LAGOON	448086	10/28/91	10,000,000	9,200,000				34100
LAGOON	188110	04/27/92	310,000	130,000				38900
LAGOON	298136	07/14/92	420,000 X	80,000		14.8		7760
LAGOON	438086	10/19/92	3,500,000	2,100,000				7810
LAGOON	188161	04/26/93	NT	NT				28300
MW1	098051	02/27/91	1 U	1 U			0.6 J	
MW1	218051	05/21/91	1	1 U				
MW1	338156	08/13/91	1 U	1 U				
MW1	448081	10/28/91	1 U	1 U				
MW5	298130	07/14/92	1	1 U	9.4			
MW5	438080	10/19/92	1 U	1 U				
MW5	038105	01/11/93	1	1 U				
MW5	188155	04/26/93	NT	NT	9.9			
MW2	098052	02/27/91	1 UX	1 U			6.5 J	
MW2	218052	05/21/91	1 U	1 U				
MW2	338157	08/13/91	1 U	1 U				
MW2	448082	10/28/91	1 UX	1 U				
MW2	188106	04/27/92	1 U	1 U				
MW2	298132	07/14/92	1 U	1 U		5.3		
MW2	438082	10/19/92	1 U	1 U				
MW2	038107	01/11/93	1 U	1 U				
MW3	098053	02/27/91	14	6 X			23 J	
MW3	218054	05/21/91	1 X	1 U				
MW3	338158	08/13/91	1 UX	1 U				
MW3	448083	10/28/91	1 UX	1 U				
MW3	188107	04/27/92	1 UX	1 U				

Table F-4 Continued.

Site Name	ID #	Date	Total Coliforms (CFU/100mL)	Fecal Coliforms (CFU/100mL)	Iron, Dissolved	Iron, Total Recover.	Total Persulfate Nitrogen	Total Solids
MW3	298133	07/14/92	1 U	1 U		5.3		
MW3	438084	10/19/92	1 UX	1 U				
MW3	038109	01/11/93	1 U	1 U				
MW3	188158	04/26/93	NT	NT	0.88			
MW4	098054	02/27/91	1 U	1 U			7.3 J	
MW4	218055	05/21/91	2000 J	180 J				
MW4	338159	08/13/91	3 X	1 UX				
MW4	448085	10/28/91	1 UX	1 U				
MW4	188109	04/27/92	1 UX	1 U				
MW4	298135	07/14/92	1 U	1 U		1.7		
MW4	438085	10/19/92	1 U	1 U				
MW4	038110	01/11/93	1 X	1 U				
MW6	298131	07/14/92	3 U	3 U		158		
MW6	438081	10/19/92	1 U	1 U				
MW6	038106	01/11/93	1 U	1 U				
MW6	188156	04/26/93	NT	NT	2.9			

J= Estimated value.

U= Analyte not detected above listed value.

NT= Not tested.

CFU= Colony forming unit.

Table F-5. Hornby Dairy, Water Quality Results April 1990 through March 1993. (Units=mg/L)

Site Name	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Persulfate Nitrogen	Total Phosphorus	Chloride
SETTLING POND #1	04/25/90	1600	2810	803	130	0.06		7.5	103
SETTLING POND #1	01/29/91		890	406	18.8 J	0.18 J	0.01 U	26.2	92.4
SETTLING POND #1	10/25/91	1160	410	138	160	0.02 U		23	105
SETTLING POND #1	06/08/92	1370	1000	286	113	0.024		27	87.1
SETTLING POND #1	12/15/92		1800	429	101	0.307		24	60.3
MAIN LAGOON	04/25/90	1990	1830	733	153	0.06		6.84	151
MAIN LAGOON	07/03/90	1630	1470	404	114	0.02		44.6	112
MAIN LAGOON	11/06/90	1220	26	147	142	0.14		27.1	117
MAIN LAGOON	09/15/92		829	735	93.9	0.129		22.9	72.9
MAIN LAGOON	03/15/93	1440	1540	413	99	0.163		28.5	75
MW1	04/25/90	911	23.9	33	0.2	7.68		0.03	10.7
MW1	07/03/90	904	39.9	10.6	0.39	6.61		0.07	10.6
MW1	11/06/90	835	11	58.3	0.02	7.63		0.02	11.4
MW1	01/28/91	825	10 U	18.1	0.008 J	5.8 J	7.32	0.013	11.5
MW1	10/25/91	728	11	8.33	0.04 U	9.3		0.15	13.4
MW1	06/08/92	778	21	8.2	0.186	10.4		0.037	15.4
MW1	09/14/92	775	19	13.2	0.103	8.7		0.012	11.8
MW1	12/14/92	776	10 U	5	0.05	7.94		0.036	11.2
MW1	03/15/93	730	13.5	5.6	0.046	8.02		0.044	10.8
MW2	04/25/90	1660	102	36.6	1.2	96		0.15	84.3
MW2	07/03/90	1210	66	13.6	3.53	56.7		0.05	61.8
MW2	11/07/90	1420	32	42	2.74	94.3		0.25	82.8
MW2	01/29/91	1310	15	14	0.37 J	64.6 J	65.2	1.73	72.4
MW2	10/25/91	1090	53	17.1	0.77	27		1.5	102
MW2	06/08/92	1300	62	22.9	0.332	31		0.202	100
MW2	09/15/92	1370	55	25.4	0.697	9.68		0.01 U	112
MW2	12/15/92	1470	70	24.6	0.14	3.09		0.233	123
MW2	03/16/93	1600	57	26.9	0.013	0.038		0.055	128
MW3	04/25/90				0.07	2.69		0.06	10.9
MW3	07/03/90	715	35.4	7.4	0.1	2.36		0.06	33

Table F-5 Continued.

Site Name	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Persulfate Nitrogen	Total Phosphorus	Chloride
MW3	11/07/90	671	19	16.1	0.34	0.06		0.04	71.2
MW3	01/29/91	677	10 U	13.1	0.005 U	0.03 J	0.23	0.31	71.7
MW3	10/25/91	1040	26	12.4	0.04 U	0.03		0.06	97.8
MW3	06/08/92	1170	39	16.8	0.01 U	0.01 U		0.029	98.7
MW3	09/15/92	1150	48	20.5	0.222	4.23		0.01 U	99.6
MW3	12/14/92	1220	28	11.5	0.287	15.7		0.032	110
MW3	03/15/93	1290	25.7	14.6	0.172	5.06		0.029	110
MW4	04/25/90	598	184	34.5	0.2	4.02		0.07	7.86
MW4	07/03/90	410	18.7	6	0.13	1.33		0.11	3.3
MW4	11/07/90	865	11	9.64	0.98	82		0.03	80.1
MW4	01/29/91		10 U	9.8	0.46 J	19.2 J	20.5	0.24	147
MW4	10/25/91	1010	18	8.8	0.21	6		0.02	66.5
MW4	06/08/92	1780	33	15.1	0.636	83.7		0.02	104
MW4	09/15/92	1620	28	25.8	0.413	27.1		0.01 U	103
MW4	12/15/92	1350	31	12.3	0.261	12.7		0.035	105
MW4	03/16/93	1210	23.4	11	0.01 U	0.01 U		0.016	107
MW5	04/25/90	856	20.2	42.8	0.14	5.79		0.03	20.1
MW5	07/03/90	753	38.3	7.5	0.22	2.42		0.11	28.9
MW5	11/07/90	699	15	30.7	0.15	0.48		1.87	56.4
MW5	01/29/91	901	10 U	18	0.02 J	0.05 J	0.15	0.036	68.9
MW5	10/25/91	983	15	7.16	0.04 U	0.04		0.03	83.6
MW5	06/08/92	1050	35	10.8	0.01 U	0.01 U		0.016	96.5
MW5	09/15/92	1010	24	17.5	0.022	0.01 U		0.04	91
MW5	12/15/92	1050	20	7.8	0.018	0.01 U		0.072	101
MW5	03/16/93	1030	19.2	9.8	0.01 U	0.01 U		0.04	101
DAVIS	11/07/90	436	5 U	18.7	0.005 U	1.72		0.05	9.23
DAVIS	01/29/91	452	10 U	29.6	0.005 U	1.3 J	1.6	0.05	8.2
DAVIS	10/25/91	440	2.6 U	2.25	0.04 U	1.5		0.04	8.7
DAVIS	09/14/92	441	10	5.0	0.01 U	1.56		0.046	8.7
DAVIS	12/14/92	413	10 U	1.2	0.01 U	1.68		0.055	8.8
DAVIS	03/15/93	420	5 U	1.1	0.01 U	1.74		0.057	9.5

Table F–6. Sheridan Dairy, Water Quality Results June 1991 through April 1992.

Site Name	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as N	Nitrate+ Nitrite as N	Total Inorganic Nitrogen	Total Persulfate Nitrogen	Total Phosphorus	Chloride	Total Solids
Lagoon	06/18/91		2100	724	230	0.07	230	130 J	140	158	46201
Lagoon	09/16/91	5800	10785	1900 J	360	0.23	360	NT	150 J	380	NT[2]
Lagoon	01/07/92	9180 J	7300	1990	594 J	0.07 J	594	NT	125 J	463	8820
MW4 Upgradient	06/18/91	557	11	5.5	0.67	0.01 U	0.67	0.4 J	0.47	44	
MW4	09/16/91	590	40	5.8 J	0.50	0.02 U	0.50	NT	0.27	38	
MW4	01/07/92	643	23	6.1	0.71	0.01 U	0.71	NT	0.09	40	
MW4	04/14/92	571	18	6.4	0.73	0.01 U	0.73	NT	0.10	38	
MW1 Downgradient	06/18/91	458	10 U	1.4	0.08	0.01 U	0.08	0.1 U	0.19	29	
MW1	09/16/91	340	3.1	2.4 J	0.04 U	0.02 U	NA	NT	0.18	25	
MW1	01/07/92	364	5.0	1.1	0.07	0.01 U	0.07	NT	0.12	24	
MW1	04/14/92	342	2.3	1.4	0.07	0.01 U	0.07	NT	0.18	27	
MW2 Downgradient	06/18/91	463	11	2.5	0.13	1.6	1.7	1.8	0.54	45	
MW2	09/16/91	450	8.4	3.8 J	0.04 U	2.7	2.7	NT	0.17	39	
MW2	01/07/92	502	6.8	2.5	0.07	2.9	3.0	NT	0.13	45	
MW2	04/14/92	417	9.3	2.6	0.01 U	2.7	2.7	NT	0.10	42	
MW3 Downgradient	06/18/91	334	10 U	1.0 U	0.03	3.6	3.6	3.6	0.13	22	
MW3	09/16/91	295	6	1.9 J	0.04 U	2.4	2.4	NT	0.30	29	
MW3	01/07/92	344	5.5	1.3	0.02	3.1	3.1	NT	0.14	24	
MW3	04/14/92	307	4.8	2.0	0.01 U	4.7	4.7	NT	0.12	19	

1Total suspended solids = 880 mg/l

[2]Total suspended solids= 5400 mg/L

J= Estimated value.

U= Analyte not detected above reported limit.

NA= Not applicable.

Table F–7. Sheridan Dairy Lagoon Bacteriologic Results.
(Units= Colony Forming Units (CFUs)/100 ml)

Site Name	Date	Total Coliform		Fecal Coliform	
Lagoon	06/18/91	430000	X	360000	
Lagoon	09/16/91	150000		120000	
Lagoon	01/07/92	800000		520000	
MW4 Upgradient	06/18/91	1		1	U
MW4	09/16/91	1	UX	1	U
MW4	01/07/92	1	U	1	U
MW4	04/14/92	1	U	1	U
MW1 Downgradient	06/18/91	1	U	1	U
MW1	09/16/91	1	U	1	U
MW1	01/07/92	1	U	1	U
MW1	04/14/92	1	U	1	U
MW2 Downgradient	06/18/91	1	UX	1	U
MW2	09/16/91	1	U	1	U
MW2	01/07/92	1	U	1	U
MW2	04/14/92	1	U	1	U
MW3 Downgradient	06/18/91	1	UX	1	U
MW3	09/16/91	1	U	1	U
MW3	01/07/92	1	U	1	U
MW3	04/14/92	1	U	1	U

X= Many Background Organisms.

U= Analyte Not Detected Above Reported Limit.