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Ground Water Quality Assessment
Hornby Dairy Lagoon
Sunnyside, Washington

by
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ABSTRACT

The Department of Ecology's Environmental Investigations and Laboratory Services Program (EILS) monitored ground water quality for one year at a new two-stage dairy lagoon (two settling ponds and a main lagoon) in Yakima County. This study was conducted at the request of the Water Quality Program as part of a larger effort to define the impact of dairy lagoons on ground water quality at several locations in Washington State. The results of these studies will be used to augment existing dairy waste management programs.

Monitoring wells were installed and sampled quarterly beginning about three months after initial placement of liquid manure. Analytes included chloride, total dissolved solids, total organic carbon, chemical oxygen demand, total phosphate-P, ammonia-N, and nitrate+nitrite-N. The estimated ambient ground water flow velocity ranged from 0.0009 to 0.08 feet per day (0.3 to 29 feet/year) with a geometric mean of about 0.005 feet per day (1.8 feet/year). Chloride concentrations in all wells downgradient of the main lagoon increased after the second and third quarters of monitoring (between four and ten months after the main lagoon received wastewater) probably due to leakage from the lagoon. At the onset of monitoring, one well downgradient of the settling ponds showed elevated concentrations of most parameters relative to the upgradient well. Two potential sources for the elevated concentrations are the settling ponds and an old lagoon that was replaced by the new lagoons. The closest water-supply well (located about 200 feet downgradient of the main lagoon) was unaffected during the course of the study. Based on the estimated ground water velocities, the long-term effects of lagoon leakage on ground water quality were probably not observed in the first year of sampling. For this reason, additional monitoring is recommended to determine if concentrations for other parameters increase downgradient of the main lagoon and to determine if chloride concentrations decrease. This continued monitoring would require authorization by the Water Quality Program based on alignment with their priorities.

ACKNOWLEDGEMENTS

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INTRODUCTION

Problem Statement

Dairy lagoons temporarily store animal wastes and wastewater during winter when nutrient uptake by cover vegetation and crops is low and the potential for surface runoff and ground water contamination from land application of wastes is high. However, leakage from dairy lagoons may contaminate ground water. Reese and Loudon (1983) summarized past studies on dairy lagoon sealing. In general, these studies concluded that dairy lagoons are to some degree self-sealing and that leakage rates decrease substantially after lagoons are initially filled. Research into the causes and mechanisms related to self-sealing of dairy lagoons suggests that at least a partial seal, consisting of settled solids, a microbial layer or a combination of both, restricts leakage from lagoons. Also, leakage rates and the rates of sealing appear to be largely a function of soil texture and pore size (Reese and Loudon, 1983). Although researchers agree that leakage rates decrease after lagoons first receive wastes, there is disagreement on the effectiveness of seals and whether the leakage rates pose a potential significant threat to ground water quality.

The Ground Water Quality Unit of the Ecology Water Quality Program requested that the Toxics, Compliance, and Ground Water Investigations Section assess ground water quality near selected dairy lagoons in Washington. Four lagoons were selected: two in Whatcom County, one in Yakima County, and one in Lewis County. Monitoring at the lagoons was initiated sequentially, and Hornby Dairy Lagoon (Yakima County) was the second in the series. This report presents and discusses the first year of results at the Hornby Dairy Lagoon. The results of the first lagoon (Edaleen Dairy Lagoon, Whatcom County) have been described previously by Erickson (1991).

Lagoon History

The Hornby Dairy is located in Yakima County about three miles southeast of Sunnyside, Washington (Figure 1). The lagoon system was designed by the Soil Conservation Service (SCS, 1989) and was constructed in the fall of 1989. The two-stage lagoon system, designed to handle manure and wastewater for about 1200 dairy cows, consists of two primary settling ponds followed by a secondary main lagoon. The settling ponds are filled alternately. When one pond becomes full of solids, slurry and liquids are directed to the other settling pond to allow drydown of the solids. After solids are dry enough for handling they are removed so that the pond can be refilled. The settling ponds are each 90 by 208 feet (inside dimensions, top of embankment) with a maximum capacity of 0.44 million gallons. The main lagoon is 188 by 516 feet with a maximum capacity of 5.05 million gallons. The lagoons began operating around January 1990.

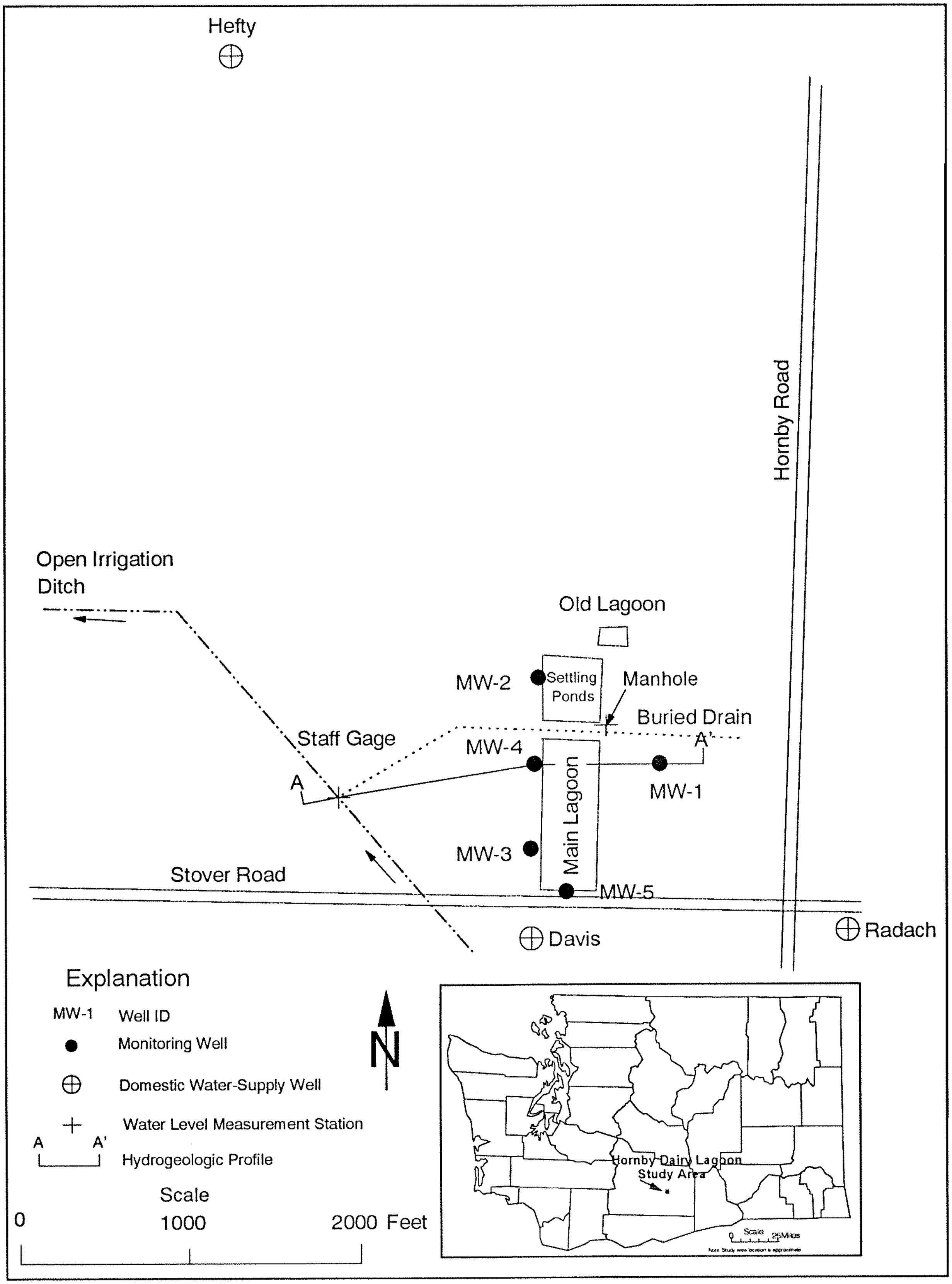

Figure 1. Hornby Dairy and Well Location Map.

Geology, Hydrogeology, and Soils

The site is underlain by stream and floodplain deposits (Campbell, 1977). A driller's log for a domestic well (Davis) about 200 feet south of the lagoon 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 well taps water from the lower sand and gravel layer. Figure 2 shows the relationship of the site hydrogeology and the lagoons.

Surficial soils are Sinloc and Warden fine sandy loams (Lenfesty and Reedy, 1985). Sinloc soils underlie the main lagoon, and Warden soils underlie the settling ponds. Generally the permeability of both soils range from 0.6 to 2 inches/hour (1.2 to 4 ft/day), however the permeability for the Sinloc soil increases to 2 to 6 inches/hour at depths greater than 45 inches.

METHODS

General

A ground water monitoring network was installed around the lagoons to obtain ground water quality samples and to define directions and rates of ground water flow. Wells and the lagoon were sampled quarterly from April 1990 to January 1991. The well samples were tested for ammonia-N, nitrate+nitrite-N, total phosphate, total organic carbon (TOC), chemical oxygen demand (COD), total dissolved solids (TDS), and chloride. Total persulfate nitrogen (TPN) was tested the last sampling round in January 1991. Lagoon samples also were tested for total suspended solids.

The monitoring network 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 (Figure 1). Water levels were measured each sampling episode in the wells, the staff gage, and the drains. The water level measurements were converted to relative elevations using mean sea level as a common datum. The differences in the water level elevations were used to determine ground water gradients and flow directions. Slug tests were conducted in the monitoring wells to estimate hydraulic conductivity of the aquifer. The hydraulic conductivity and ground water gradient data were combined to estimate ground water flow velocities. The methods are described in detail below.

Well Installation and Water Levels

Five monitoring wells consisting of a two foot-long, commercial, stainless steel wellpoint and a 1 1/4-inch diameter galvanized pipe were driven to the desired depth. Well screens and casing were steam cleaned before installation. Bentonite surface seals were installed at each well by augering an oversized hole, about six inches in diameter, and placing hydrated 1/2-inch bentonite pellets in the annular space. Hydrated bentonite was added to the annular space during well

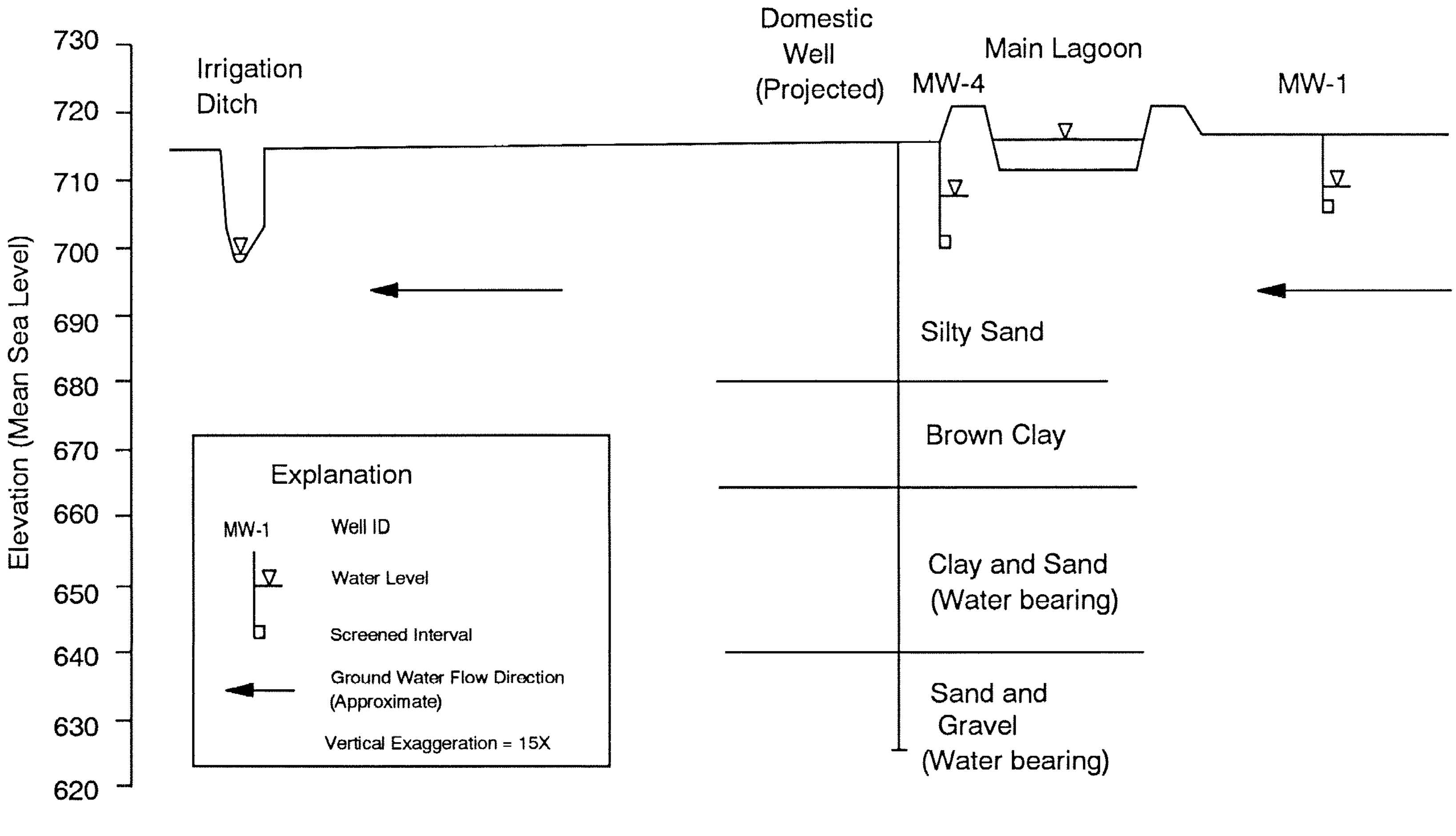

Figure 2. Hornby Dairy Lagoon, Hydrogeologic Profile A-A'

driving to reduce sidewall friction. A summary table of well construction data and as-built drawings for each well are shown in Appendix A, Table A-1. All wells, with the exception of MW-5, were developed by surging with a one-way bottom valve attached to 3/4-inch PVC. MW-5 was partially obstructed and the development tool could not be lowered to the screened area.

Water levels were obtained using a commercial electric well probe. Relative elevations of measuring points for the monitoring and domestic wells, the staff gage, and the buried drain were determined using a surveyor's level and rod. All elevations were measured relative to a bench mark set on a concrete footing in the southwest corner of a nearby corral. A base elevation of 720 feet (mean sea level) was assumed for the bench mark using a USGS 7.5 minute topographic map. Relative elevations are considered to be accurate to 0.05 feet for on-site wells and 0.5 feet for off-site wells.

Slug Tests

Slug withdrawal tests were conducted to estimate *insitu* hydraulic conductivity at the four monitoring wells that were developed (MW-1 through MW-4). The wells were rapidly pumped and the recovering water levels were measured at selected time intervals using an electric well probe. The recovery data were evaluated using two methods: 1) Bouwer and Rice (1976), using a computer software package developed by Duffield and Rumbaugh (1989); and 2) a modification of Hvorslev (1951) and Cedergren (1977), using a computer program developed by Thompson (1987). Both methods are appropriate for unconfined conditions with partially penetrating wells. Appendix B contains the raw data and recovery curves.

Sampling and Analysis

Wells were purged and sampled using a peristaltic pump attached to dedicated 3/8-inch OD polyethylene or Tygon tubing. The peristaltic pump head used flexible silastic tubing. With the exception of MW-1, the monitoring wells have low yields. Prior to sampling, they were purged dry and allowed to recover, usually overnight. Often, small sample volumes were available. Additionally, slow recovery impeded our ability to assure the stabilization of water quality prior to sampling. MW-1 had a higher yield. Because of this water quality results from this well may be less variable. MW-1 was sampled after purging a minimum of three well volumes and pH, specific conductance and temperature measurements stabilized. Grab samples from the lagoon were collected just below the wastewater surface. All samples were placed in coolers at 4°C and transported to the Ecology/EPA Region X Laboratory in Manchester, Washington. The parameters tested, test methods, and method detection limits are listed in Table 1.

RESULTS

Hydraulic Conditions

Depth to the water table ranged from about five to ten feet. The water levels fluctuated one to two feet over the course of the study. Water levels are shown in Appendix C. Differences in

Table 1. Hornby 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 Phosphate-P	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

water levels between wells indicate that ground water moves generally westward toward the open irrigation ditch. Water-table contour maps based on water level data for May 1990 and January 1991, are shown in Figures 3 and 4. Ground water moves perpendicular to the contours from high to low elevations. The contour maps are approximate because the domestic wells in the network are 50 to 100 feet deeper than the monitoring wells and no allowance has been made for vertical hydraulic gradients. Also, the driller's log for the Davis well shows 15 feet of fine-grained material, a potential hydraulic barrier, between 35 to 50 feet deep.

The slug test results (Table 2) yield hydraulic conductivities of 0.04 to 0.9 feet per day. The estimates of the two evaluation methods, Bouwer and Rice (1976) and Thompson (1987), compare favorably. The geometric mean for hydraulic conductivity is 0.15 feet per day. Because hydraulic conductivity is considered to be log-normally distributed (Freeze, 1986) the geometric mean is more representative of average conditions than the arithmetic mean.

Ground water velocities can be estimated using Darcy's Law:

$$v = \frac{K_h \times \frac{dh}{dL}}{n_e}$$

where,

v = estimated average linear velocity
dh/dL = hydraulic gradient
K_h = saturated hydraulic conductivity
n_e = effective porosity

Table 2. Slug Test Results, Hydraulic Conductivity (feet/day)

Well ID	Bouwer and Rice (1976)	Thompson (1987)
MW-1	0.5	0.9
MW-2	0.04	0.06
MW-3	0.15	0.2
MW-4	0.06	0.1
MW-5	Not Tested	Not Tested
Geometric Mean	0.12	0.18

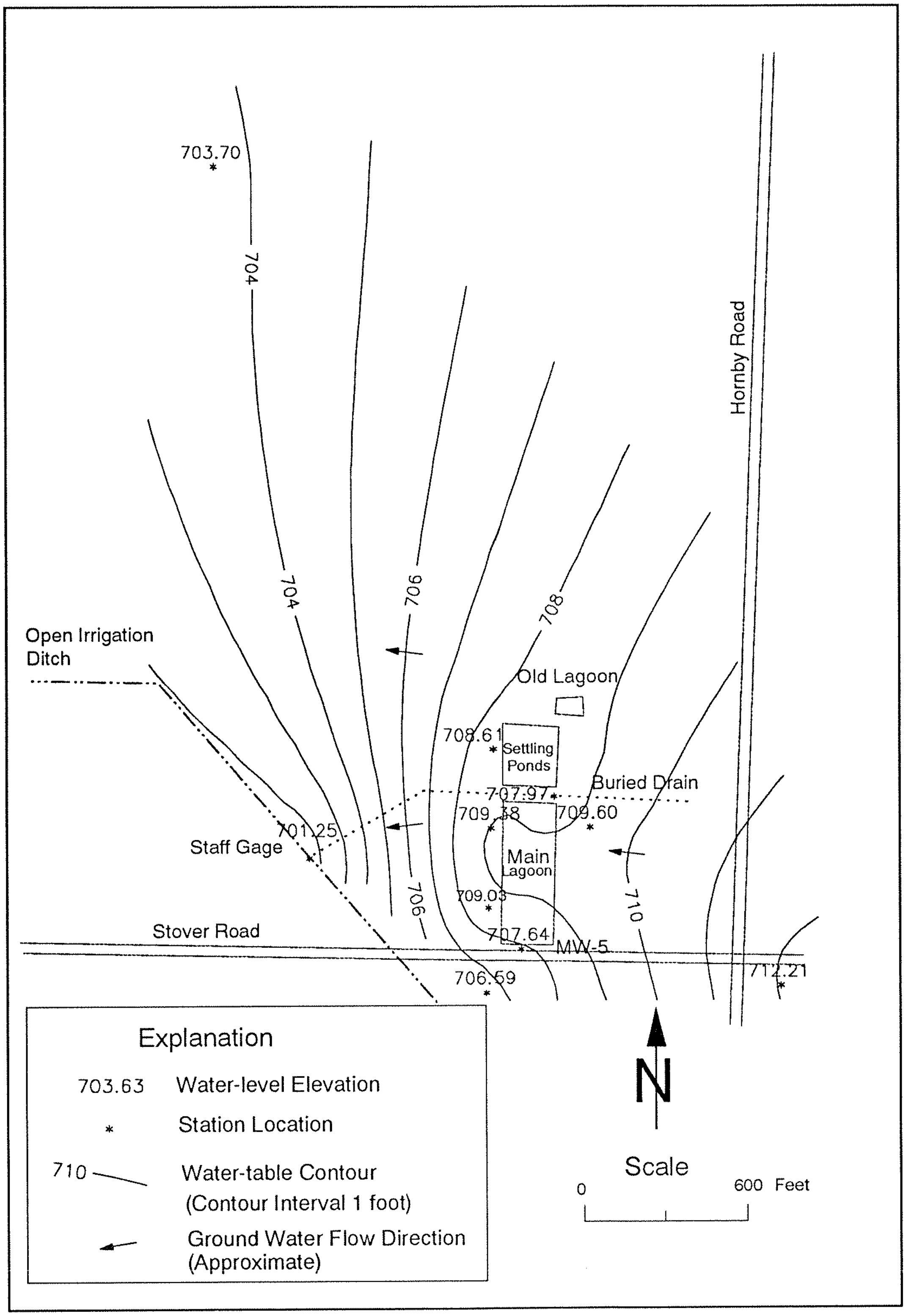

Figure 3. Water-Table Contour Map, May 1990

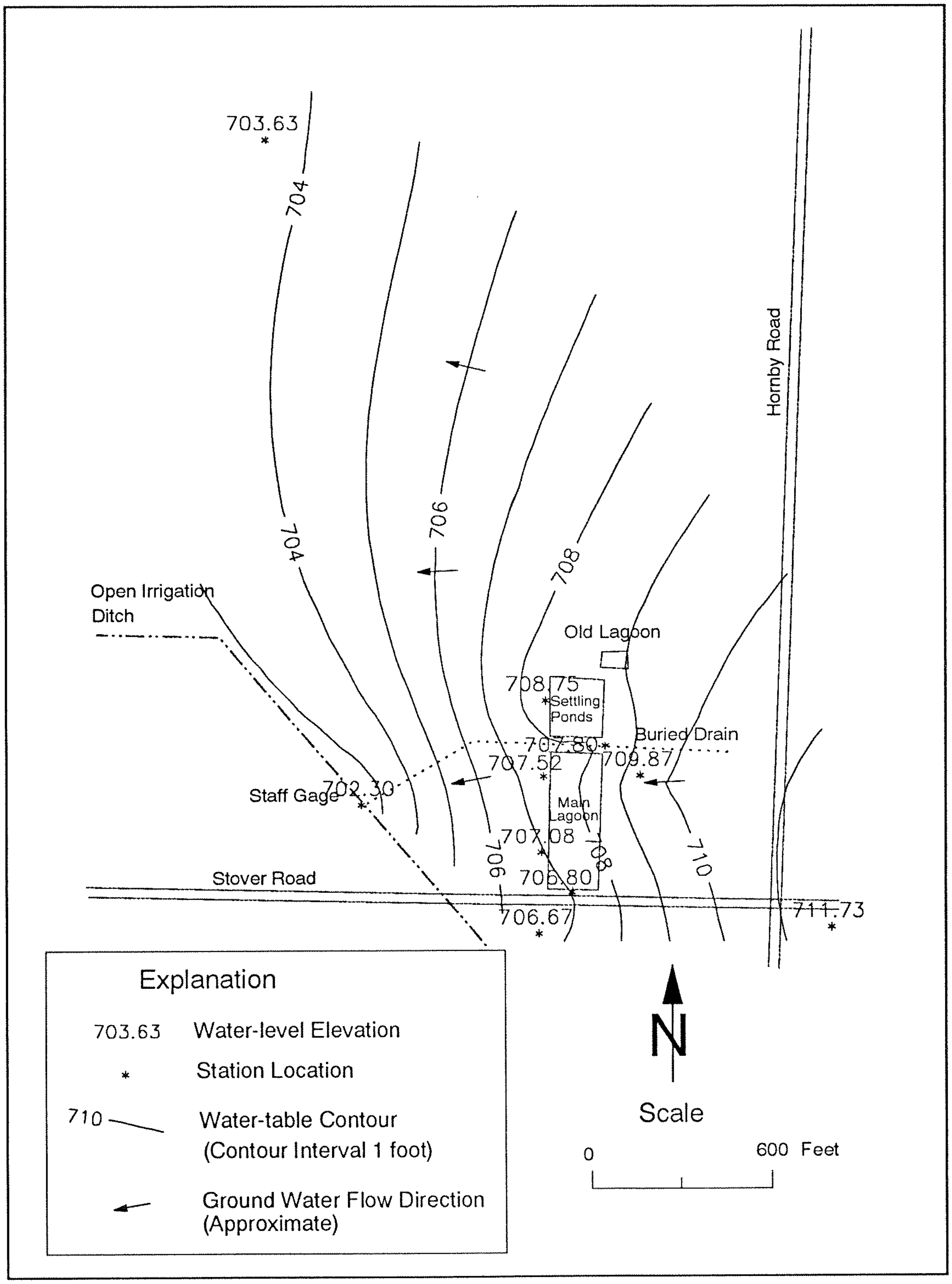

Figure 4. Water-Table Contour Map, January 1991.

Because the aquifer is unconfined and consists of unconsolidated silt and fine sand, effective porosity was assumed to range between 0.10 and 0.35. This variability combined with the range of hydraulic conductivity and hydraulic gradient, results in a range in flow velocity of 0.0009 to 0.08 feet per day (0.3 to 29 feet per year). The results are shown in Table 3. The mean linear velocity (using a hydraulic conductivity of 0.15 feet per day, and effective porosity of 0.25 and a hydraulic gradient of 0.0085 (feet/feet)) is 0.005 feet per day (1.8 feet per year).

Table 3. Estimated Ground Water Velocities.

	Maximum	Minimum	Mean
Hydraulic Conductivity (feet/day)	0.9	0.04	0.15
Effective Porosity	0.35	0.1	0.25
Hydraulic Gradient (feet/feet)	0.0089	0.0081	0.0085
Ground Water Velocity (feet/day)	0.08	0.0009	0.005

Quality Assurance

In addition to calibration standards, spikes, and laboratory duplicates, field quality assurance samples consisted of blind duplicates and TOC transport blanks. Quality assurance results are listed in Table 4. A blind duplicate sample, used to estimate analytical precision, was obtained for each parameter during each sampling event. Relative percent differences (RPDs) (the ratio of the difference of duplicate results and their mean) of duplicate results are shown in Table 4.

Overall, the quality of the data is good. 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.

Table 4. Hornby Dairy Lagoon Blind Duplicate and TOC Transport Blank Results (mg/L).

Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite-N	Total Persulfate Nitrogen	Total Phosphate as P	Chloride	Total Organic Carbon Transport Blank
4/25/90	NT	NT	36.6	1.2	96	NT	0.15	NT	0.32
Duplicate	"	"	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
Duplicate	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
Duplicate	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
Duplicate	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	

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

Water Quality

Field parameter results for pH, specific conductance and temperature are shown in Table 5. The pH of ground water ranged between 7.2 and 9.6 and was highest in wells MW-3 and MW-5. Temperature ranged from 8.5 to 16.1°C and was consistently lowest in January and highest in July. Specific conductance ranged from 468 (Davis well) to 1520 micromhos/cm (MW-2). Specific conductance was substantially higher in MW-2 (downgradient of the settling pond) than in all other wells, including the upgradient well (MW-1).

The laboratory water quality results are shown in Table 6. Near-surface grab samples were obtained from the main lagoon and a settling pond. Wastewater concentrations for total dissolved solids (1220 to 1990 mg/L), chemical oxygen demand (890 to 2810 mg/L), total organic carbon (147 to 803), ammonia-N (19 to 142 mg/L), total phosphate (6.8 to 45 mg/L), and chloride (92 to 151 mg/L) were substantially higher than upgradient concentrations (MW-1). Total suspended solids in the wastewater ranged from 80 to 2030 mg/L.

At well MW-2 total dissolved solids (TDS), chemical oxygen demand (COD), ammonia-N, nitrate+nitrite-N, total phosphate-P, and chloride concentrations were higher than upgradient concentrations at the onset of the monitoring and remained elevated for all sampling events.

DISCUSSION

Chloride was the only parameter that showed a consistent increase in monitoring wells downgradient of the main lagoon (MW-3, MW-4, and MW-5). Chloride results are shown in Figure 5. Chloride concentrations in the upgradient well were consistent (10.6 to 11.5 mg/L). In two of the downgradient wells (MW-3 and MW-5) chloride concentrations began to increase July 1990, and by November increased in all three downgradient monitoring wells (MW-3, MW-4, and MW-5). Leakage from the main lagoon is the probable cause of the concentration increases. Chloride is mobile in ground water. It is highly soluble in water and moves through soil with little or no attenuation (Davis and DeWiest, 1966; Freeze and Cherry, 1979). The highest chloride concentrations occurred during the last sampling event (January 1991); therefore, it is likely that concentrations were still increasing. Because chloride is generally more mobile than the other parameters in the wastewater, it is possible that concentrations for other parameters eventually will increase over time.

Chloride data can be used to estimate ground water velocities between the main lagoon and the monitoring wells. The distance traveled is measured from the inside of the lagoon to the monitoring wells, about 40 feet. The travel time is the interval between when the lagoon was first used and when chloride concentrations began to increase in downgradient monitoring wells. The results are summarized in Table 7. The estimated ground water velocities using the chloride date range from 0.1 to 0.4 feet per day (50 to 135 feet per year). These flow rates are

Table 5. Hornby Dairy Lagoon Field Parameter Results.

Site Name	Date	pH (Std Units)	Temperature (C)	Specific Conductance (umhos/cm)
SETTLING POND #1	04/25/90	6.78	18.9	NT
SETTLING POND #2	01/29/91	7.56	6.7	1710
MAIN LAGOON	04/25/90	7.39	17.4	NT
MAIN LAGOON	07/03/90	7.64	27.7	2250
MAIN LAGOON	11/07/90	7.69	7.8	1600
MW1	04/25/90	7.87	11	NT
MW1	07/03/90	7.96	13.7	950
MW1	11/06/90	8.56	14.4	920
MW1	01/28/91	8.73	9.0	800
MW2	04/25/90	7.42	12.3	NT
MW2	07/03/90	7.86	16.1	1250
MW2	11/07/90	7.7	14.3	1520
MW2	01/29/91	7.19	10.0	1100
MW3	04/25/90	8.28	12.8	NT
MW3	07/03/90	8.5	14.9	800
MW3	11/07/90	9.61	14.0	970
MW3	01/29/91	9.53	8.7	600
MW4	04/25/90	7.66	12.1	NT
MW4	07/03/90	8.9	15.4	670
MW4	11/07/90	8.22	14	1150
MW4	01/29/91	8.16	9.8	640
MW5	04/25/90	8.02	12.1	NT
MW5	07/03/90	9.57	15	850
MW5	11/07/90	9.61	14.7	920
MW5	01/29/91	8.64	8.5	630
DAVIS	11/07/90	7.79	14	570
DAVIS	01/29/91	7.87	12.5	468

NT= Not Tested

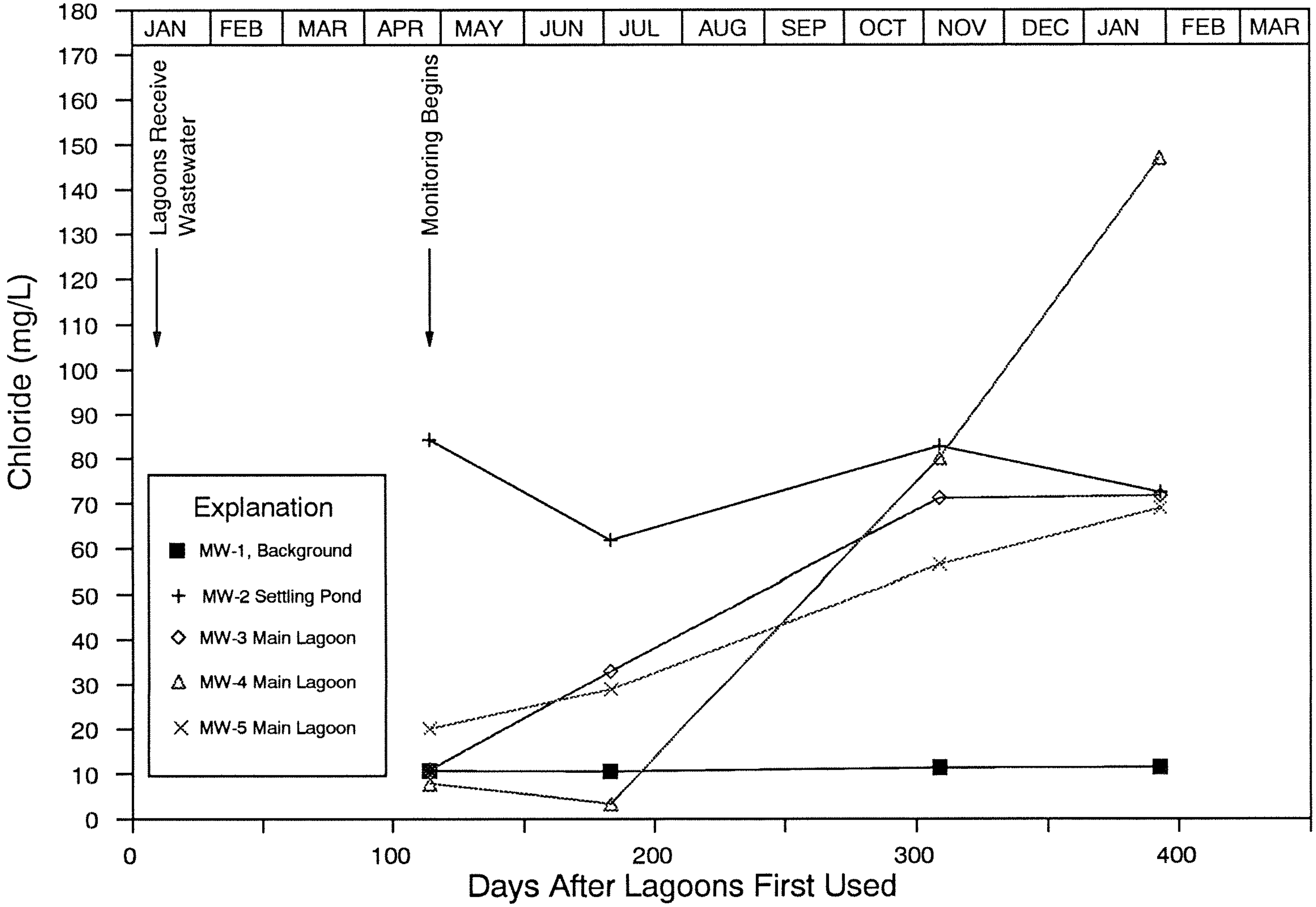

Figure 5. Hornby Dairy Chloride Concentrations in Monitoring Wells April 1990 to January 1991.

Table 6. Hornby Dairy Lagoon Water Quality Results April 1990 to January 1991 (mg/L).

Site Name	Date	Total Dissolved Solids	Chemical Oxygen Demand	Total Organic Carbon	Ammonia-N	Nitrate+ Nitrite-N	Total Inorganic Nitrogen	Total Persulfate Nitrogen	Total Phosphate as P	Chloride	Total Suspended Solids
Settling Pond #1	04/25/90	1600	2810	803	130	0.06	130.1	NT	7.5	103	1820
Settling Pond #1	01/29/91	NT	890	406	18.8	0.18	19.0	ND	26.2	92.4	2030
Main Lagoon	04/25/90	1990	1830	733	153	0.06	153.1	NT	6.84	151	485
Main Lagoon	07/03/90	1630	1470	404	114	0.02	114.0	"	44.6	112	80
Main Lagoon	11/06/90	1220	NT	147	142	0.14	142.1	"	27.1	117	NT
MW1	04/25/90	911	23.9	33	0.2	7.68	7.9	NT	0.03	10.7	NT
MW1	07/03/90	904	39.9	10.6	0.39	6.61	7.0	"	0.07	10.6	"
MW1	11/06/90	835	11	58.3	0.02	7.63	7.6	"	0.02	11.4	"
MW1	01/28/91	825	ND	18.1	0.008	5.8	5.8	7.32	0.013	11.5	"
MW2	04/25/90	1660	102	36.6	1.2	96	97.2	NT	0.15	84.3	NT
MW2	07/03/90	1210	66	13.6	3.53	56.7	60.2	"	0.05	61.8	"
MW2	11/07/90	1420	32	42	2.74	94.3	97.0	"	0.25	82.8	"
MW2	01/29/91	1310	15	14	0.37	64.6	65.0	65.2	1.73	72.4	"
MW3	04/25/90	NT	NT	NT	0.07	2.69	2.8	NT	0.06	10.9	NT
MW3	07/03/90	715	35.4	7.4	0.1	2.36	2.5	"	0.06	33	"
MW3	11/07/90	671	19	16.1	0.34	0.06	0.4	"	0.04	71.2	"
MW3	01/29/91	677	ND	13.1	ND	0.03	0.0	0.23	0.31	71.7	"
MW4	04/25/90	598	184	34.5	0.2	4.02	4.2	NT	0.07	7.86	NT
MW4	07/03/90	410	18.7	6	0.13	1.33	1.5	"	0.11	3.3	"
MW4	11/07/90	865	11	9.64	0.98	82	83.0	"	0.03	80.1	"
MW4	01/29/91	NT	ND	9.8	0.46	19.2	19.7	20.5	0.24	147	"
MW5	04/25/90	856	20.2	42.8	0.14	5.79	5.9	NT	0.03	20.1	NT
MW5	07/03/90	753	38.3	7.5	0.22	2.42	2.6	"	0.11	28.9	"
MW5	11/07/90	699	15	30.7	0.15	0.48	0.6	"	1.87	56.4	"
MW5	01/29/91	901	ND	18	0.02	0.05	0.1	0.15	0.036	68.9	"
Davis	11/07/90	436	5	18.7	0.005	1.72	1.7	NT	0.05	9.23	NT
Davis	01/29/91	452	ND	29.6	ND	1.3	1.3	1.6	0.05	8.2	"

J= Estimated Value U= Analyte not detected above the reported concentration.

ND= Not detected NT= Not tested.

Table 7. Estimated Ground Water Velocities Using Chloride Results.

Well ID	Distance from Lagoon (feet)	First Arrival Time (days)	Estimated Ground Water Velocity (feet/day)	Estimated Ground Water Velocity (feet/year)
MW-3	40	110 to 180	0.2 to 0.4	80 to 135
MW-4	40	180 to 300	0.1 to 0.2	50 to 80
MW-5	40	110 to 180	0.2 to 0.4	80 to 135

substantially higher than the estimated rates using Darcy's Law. Mounding of the water table beneath the lagoon (Figure 3) is a possible explanation for the higher velocity based on the chloride data. Mounding would increase hydraulic gradients locally which would increase observed flow velocities between the lagoon and the monitoring wells. If this is the appropriate explanation, then the velocities beyond the monitoring wells should be closer to those estimated in Table 3.

Nitrogen is present in the wastewater primarily as ammonia at concentrations ranging from 19 to 153 mg-N/L. Background concentrations of nitrate+nitrite-N (MW-1) ranged from 5.8 to 7.7 mg/L. The nitrate+nitrite-N concentration in well MW-4, downgradient of the main lagoon, increased to 82 mg/L in November. The concentration decreased to 19 mg/L in January. Because other downgradient monitoring wells did not show similar increases in nitrate+nitrite-N it is not known whether the increase was due to leakage from the lagoon. According to the dairy waste inspector, the dairy opened a discharge pipe and directly discharged wastewater to ground at the toe of the main lagoon embankment near MW-4. Also, wastewater from the lagoons was applied to the field adjacent to MW-4. The observed increased nitrate-nitrite-N may be an effect of these activities.

The cause of the high concentrations of total dissolved solids, chemical oxygen demand, ammonia-N, nitrate+nitrite-N, total phosphate-P, and chloride in MW-2 is unknown. Two potential sources for the contamination are the settling ponds and the old lagoon that was replaced by the new lagoon system. The fact that high concentrations were observed in MW-2 only four months after the settling ponds were first used may imply that the ponds were not the initial cause of this contamination. Considering chloride travel times observed at the main lagoon, there was insufficient time for contaminants to migrate from the settling ponds to MW-2 via ground water. The other potential source, the old lagoon, was located near the northeast corner of the settling ponds (Figure 1). Although the old lagoon was not directly upgradient of MW-2 (Figures 3 and 4), ground water flow direction probably varies seasonally and over the long term, and it is possible that contaminants from the old lagoon may have migrated to MW-2.

Drinking water standards (Maximum Contaminant Levels, MCLs) for public systems and ground water quality standards (Chapter 173-200 WAC) are shown in Table 8 for the parameters tested.

Table 8. Hornby Dairy Lagoon, Drinking Water Standards and Ground Water Quality Standards (mg/L unless shown otherwise).

Parameter	Primary Maximum Contaminant Level(MCL)*	Secondary Maximum Contaminant Level(MCL)**	Ground Water Quality Standards***
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+Nitrite-N	10	None	10
Total Phosphate	None	None	None
Specific Conductance (micromhos/cm)	None	700	None

*Department of Health (1989). Primary MCLs are maximimum allowable contaminant concentrations for public water supply systems based on potential adverse health effects.
**Department of Health (1989). Secondary MCLs are maximum allowable contaminant concentrations for public water supply systems based on aesthetics such as taste, odor, or staining.
*** Chapter 173-200 WAC, Water Quality Standards for Ground Waters of the State of Washington.

Only one parameter, nitrate-N (10 mg/L), has a primary MCL. Primary MCLs are maximum allowable concentrations for public water-supply systems based on potential health effects (Department of Health, 1989). Nitrogen is present in the wastewater primarily as ammonia-N, portions of which are expected to mineralize to nitrite and nitrate. Nitrate+nitrite-N concentrations exceeded the MCL in two monitoring wells MW-2 and MW-4. Based on the ground water flow directions, ground water near these wells will discharge eventually to the open irrigation ditch to the west.

Secondary MCLs have been established for public drinking water systems for three of the parameters tested: specific conductance (700 micromhos/cm), TDS (500 mg/L), and chloride (250 mg/L). Secondary MCLs are based on aesthetics such as taste, odor, or discoloration. Specific conductance measurements and TDS concentrations exceeded the Secondary MCL for all on-site wells (including the background well but not the Davis well) for nearly all measurements. Chloride concentrations in the wastewater were less than the Secondary MCL.

One domestic water-supply well (Davis), located about 200 feet downgradient of the lagoon, obtains water from a depth of 85 feet. To some degree, this well may be protected from potential contamination by a 15-foot thick, fine-grained layer between 35 to 50 feet deep. Because the continuity of this fine-grained layer is unknown, a potential for contamination from long-term leakage of the lagoon exists. Samples obtained from the well in November and January showed no effects due to lagoon leakage.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions from the first year of monitoring at the Hornby Dairy Lagoon are discussed below.

1. Ground water immediately downgradient of the newly constructed main lagoon first showed elevated concentrations of chloride after the second and third quarters of sampling. The chloride concentrations were highest during the last sampling event (January 1991), which suggests that concentrations were still increasing. The increased concentrations are probably the result of leakage from the main lagoon.

2. Water quality results for other parameters (total dissolved solids, chemical oxygen demand, total organic carbon, ammonia-N, nitrate+nitrite-N, and total phosphate-P) did not show consistent increases or changes. However, these parameters generally are less mobile in ground water than chloride, and the monitoring period (one year) may not have been long enough for the contaminants to reach the monitoring wells.

3. Concentrations for most parameters downgradient of the settling ponds (MW-2) were elevated relative to upgradient concentrations at the onset of monitoring and remained elevated throughout the study. Two potential sources of contamination are the settling ponds

and the old lagoon that was replaced by the new lagoon system. Evidence based on ground water velocities implies that the settling ponds were probably not responsible for the initial contamination in MW-2.

4. Water-table contour maps show that ground water near the lagoon flows toward the west and south. The water table in May 1990 appears to be locally elevated (mounded) beneath the lagoon, due to leakage.

5. The hydraulic conductivity of the uppermost aquifer ranges from 0.04 to 0.9 feet per day based on slug withdrawal tests. The ground water flow rate, estimated using Darcy's Law, ranges from 0.0009 to 0.08 feet per day (0.3 to 29 feet per year). The ground water flow velocities based on chloride travel times range from 0.1 to 0.4 feet per day (50 to 135 feet per year). The higher flow rates using chloride data may be due to increased hydraulic gradients associated with localized mounding of the water table. Beyond the monitoring wells, away from the effects of mounding, the ground water flow rates are probably closer to those estimated using Darcy's Law.

6. The westward flow of ground water in the study area probably conveys water from beneath the lagoons to an open irrigation ditch to the west and southwest. One domestic water supply well is downgradient of the main lagoon and eventually might become contaminated if leakage continues. However, this well taps the sand and gravel aquifer at a depth of 85 feet and a 15-foot-thick, fine-grained layer may provide some natural protection.

Recommendations based on the first year of monitoring are described below.

1. Continue quarterly monitoring of on-site wells and the lagoon to determine if concentrations for other parameters increase and if chloride concentrations decrease. Continued monitoring would require authorization by the Water Quality Program based on alignment with their priorities.

2. If monitoring continues, consider adding field tests for ferrous iron, total dissolved oxygen, and laboratory tests for total iron. The low yield of the monitoring wells must be considered when determining what parameters can be added.

3. SCS should conduct a final review of the lagoon construction to determine if it meets their standards and guidelines.

4. After monitoring is terminated, on-site monitoring wells should be properly decommissioned in accordance with Chapter 173-160 WAC, Minimum Standards for the Construction and Maintenance of Wells.

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APPENDIX A

Table A-1. Well Construction Summary

Drill Logs and Well As-Built Drawings

Table A-1. Hornby Dairy Lagoon Well Location and Construction Summary.

Well ID	State Plane Coordinates X	Y	Total Depth (feet,GSD)	Measuring Point Elevation (feet, MSL)	Screened Interval (feet,GSD)	Use
MW-1	2136862	343717	13.4	719.38	11.4-13.4	Monitoring
MW-2	2136457	344044	13.9	717.55	11.9-13.9	Monitoring
MW-3	2136440	343386	13.9	716.10	11.9-13.9	Monitoring
MW-4	2136446	343715	13.6	717.03	11.6-13.6	Monitoring
MW-5	2136572	343214	13.6	716.57	11.6-13.6	Monitoring
Davis	2136428	343035	87	712.2	85	Domestic
Radach	2137674	343060	60	720.89	60	Domestic
Hefty	2135281	346466	110	712.45	110	Domestic

GSD= Ground Surface Datum
MSL= Approximate Mean Sea Level

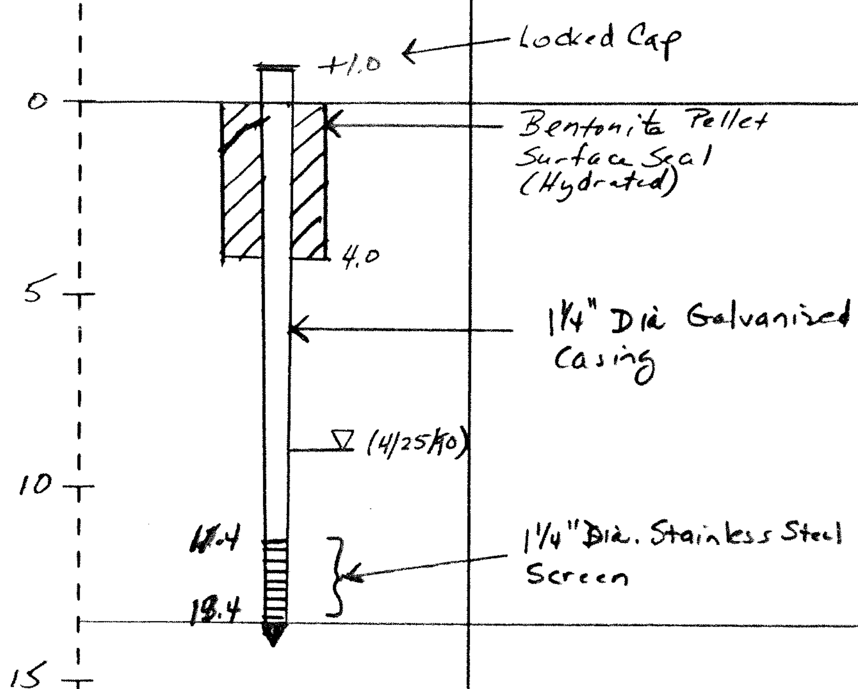
RESOURCE PROTECTION WELL REPORT

START CARD NO. 027244

PROJECT NAME: Hornby Dairy Lagoon
WELL IDENTIFICATION NO. MW-1
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Dept. of Ecology
SIGNATURE: Denis R. Erickson
CONSULTING FIRM:
REPRESENTATIVE:

COUNTY: Yakima
LOCATION: SE 1/4 SE 1/4 Sec 8 Twn 9N R 23E
STREET ADDRESS OF WELL: Stover Road Sunnyside
WATER LEVEL ELEVATION: 709.6
GROUND SURFACE ELEVATION: 718.4
INSTALLED: 4/23/90
DEVELOPED: 4/24/90

AS-BUILT	WELL DATA	FORMATION DESCRIPTION



Ground Surface

Brown silty fine to very fine SAND

Total Depth ~~14.4~~ 13.4

SCALE: 1" = 5 feet

PAGE 1 OF 1

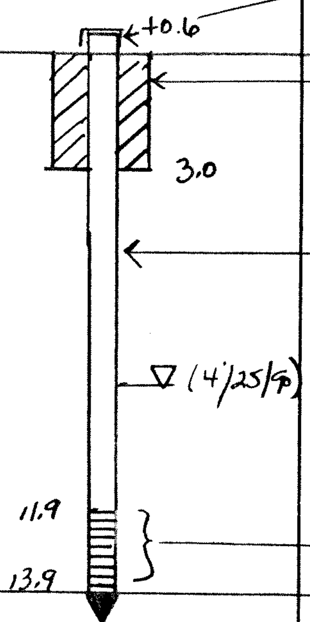
ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. 027244

PROJECT NAME: Hornby Dairy Lagoon
WELL IDENTIFICATION NO. MW-2
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Dept. of Ecology
SIGNATURE: Denis R Erickson
CONSULTING FIRM:
REPRESENTATIVE:

COUNTY: Yakima
LOCATION: SE 1/4 SE 1/4 Sec 8 Twn 9N R 23E
STREET ADDRESS OF WELL: Stover Road
Sunnyside
WATER LEVEL ELEVATION: 708.5
GROUND SURFACE ELEVATION: 717.0
INSTALLED: 4/23/90
DEVELOPED: 4/24/90

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Locked Cap	
0		Ground Surface
	Bentonite Pellet Surface Seal (Hydrated)	Brown silty fine to very fine SAND
5	1¼" Dia. Galvanized Casing	
10		
15	1¼" Dia. Stainless Steel Screen	Total Depth 13.9

SCALE: 1" = 5 feet

PAGE 1 OF 1

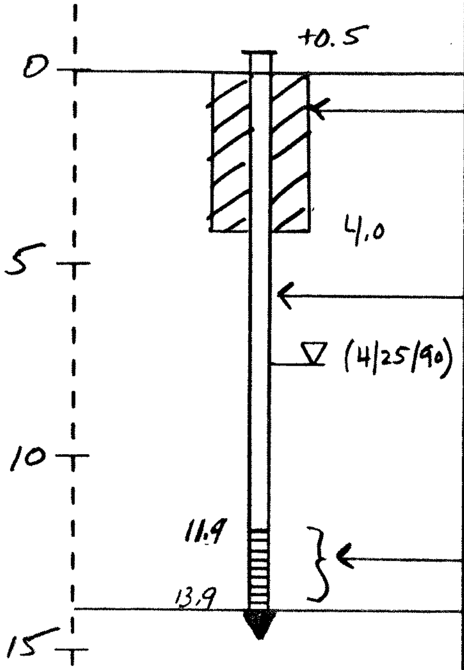
ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. 027244

PROJECT NAME: Hornby Dairy Lagoon	COUNTY: Yakima
WELL IDENTIFICATION NO. MW-3	LOCATION: SE 1/4 SE 1/4 Sec 8 Twn 9N R 23E
DRILLING METHOD: Driven	STREET ADDRESS OF WELL: Stover Road
DRILLER: Denis Erickson	Sunnyside
FIRM: Dept. of Ecology	WATER LEVEL ELEVATION: 708.0
SIGNATURE: Denis R. Erickson	GROUND SURFACE ELEVATION: 715.6
CONSULTING FIRM:	INSTALLED: 4/23/90
REPRESENTATIVE:	DEVELOPED: 4/24/90

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
+0.5	Locking Cap	Ground Surface (0)
0–4.0	Bentonite Pellet Surface Seal (Hydrated)	Brown silty fine to very fine SAND
	1¼" Dia. Galvanized Casing	
▽ (4/25/90)		
11.9–13.9	1¼" Dia. Stainless Steel Screen	
13.9		Total Depth 13.9 feet



SCALE: 1" = 5 feet

PAGE 1 OF 1

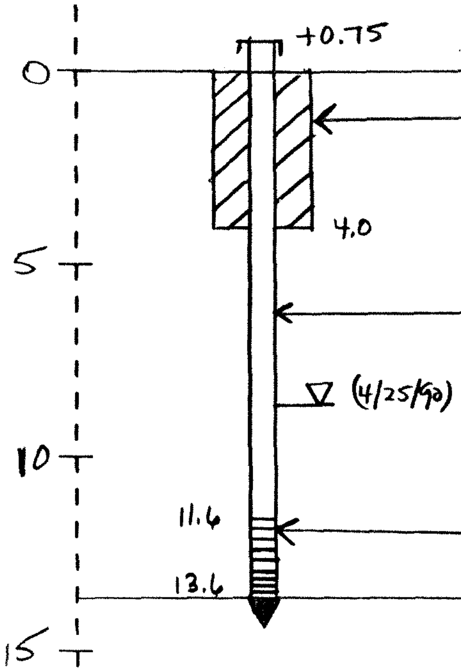
ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. 027244

PROJECT NAME: Hornby Dairy Lagoon
WELL IDENTIFICATION NO. MW-4
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Dept. of Ecology
SIGNATURE: Dennis R. Erickson
CONSULTING FIRM:
REPRESENTATIVE:

COUNTY: Yakima
LOCATION: SE ¼ SE ¼ Sec 8 Twn 9N R 23E
STREET ADDRESS OF WELL: Stover Road
Sunnyside
WATER LEVEL ELEVATION: 707.7
GROUND SURFACE ELEVATION: 716.3
INSTALLED: 4/23/90
DEVELOPED: 4/24/90

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Locking Cap	Ground Surface
	Bentonite Pellet Surface Seal (Hydrated)	Brown, silty fine to very fine SAND
	1¼" Dia. Galvanized Casing	
	1¼" Dia. Stainless Steel Screen	Total Depth 13.6

SCALE: 1" = 5 feet PAGE 1 OF 1

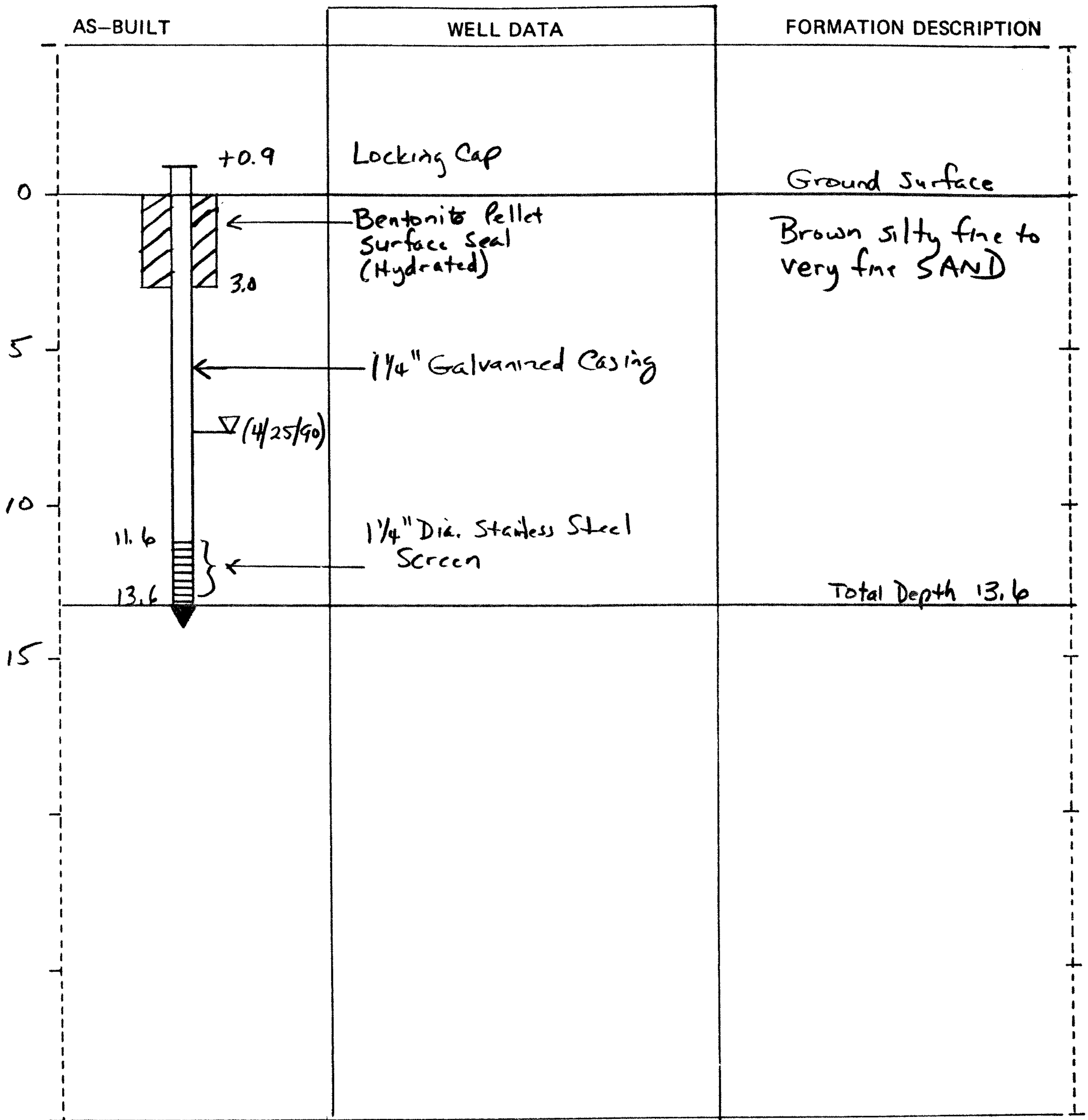
ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. 027244

PROJECT NAME: Hornby Dairy Lagoon
WELL INDENTIFICATION NO. MW-5
DRILLING METHOD: Driven
DRILLER: Denis Erickson
FIRM: Dept. of Ecology
SIGNATURE: Denis R. Erickson
CONSULTING FIRM:
REPRESENTATIVE:

LOCATION: T 9N, R 23E, SEC. 8 SE1/4 SE1/4
DISTANCE: ______ FT. FROM N/S SECTION LINE
______ FT. FROM E/W SECTION LINE
DATUM: ~msl
WATER LEVEL ELEVATION: 707.8
INSTALLED: 4/24/90
DEVELOPED: 4/24/90
GROUND SURFACE ELEV = 715.7



SCALE: 1"= 5 feet

PAGE 1 OF 1

ECY 050-12

DAVIS WELL

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. ——
Permit No. ....

(1) **OWNER:** Name FRANCIS ASLAKSON Address 702 - S 76 T Tacoma Wa 98408

(2) **LOCATION OF WELL:** County YAKIMA N½ NE¼ NE¼ Sec. 17 T. 9 N., R. 23E W.M.
Bearing and distance from section or subdivision corner 1000' W. of NE Cor Sec 17 and 140' South of Stover Rd

(3) **PROPOSED USE:** Domestic [X] Industrial [ ] Municipal [ ] Irrigation [ ] Test Well [ ] Other [ ]

(4) **TYPE OF WORK:** Owner's number of well (if more than one) ....
New well [X] Method: Dug [ ] Bored [ ]
Deepened [ ] Cable [X] Driven [ ]
Reconditioned [ ] Rotary [ ] Jetted [ ]

(5) **DIMENSIONS:** Diameter of well 6 inches.
Drilled 87 ft. Depth of completed well 87 ft.

(6) **CONSTRUCTION DETAILS:**

Casing installed: 6" Diam. from +1 ft. to 85 ft.
Threaded [ ] ....." Diam. from ..... ft. to ..... ft.
Welded [X] ....." Diam. from ..... ft. to ..... ft.

Perforations: Yes [ ] No [X]
Type of perforator used.....
SIZE of perforations ..... in. by ..... in.
..... perforations from ..... ft. to ..... ft.
..... perforations from ..... ft. to ..... ft.
..... perforations from ..... ft. to ..... ft.

Screens: Yes [ ] No [X]
Manufacturer's Name.....
Type..... Model No.....
Diam. ..... Slot size ..... from ..... ft. to ..... ft.
Diam. ..... Slot size ..... from ..... ft. to ..... ft.

Gravel packed: Yes [ ] No [X] Size of gravel: .....
Gravel placed from ..... ft. to ..... ft.

Surface seal: Yes [X] No [ ] To what depth? 18 ft.
Material used in seal.....
Did any strata contain unusable water? Yes [ ] No [X]
Type of water?..... Depth of strata.....
Method of sealing strata off.....

(7) **PUMP:** Manufacturer's Name.....
Type: ..... H.P.....

(8) **WATER LEVELS:** Land-surface elevation above mean sea level.... ft.
Static level ..... ft. below top of well Date 4-14-80
Artesian pressure ..... lbs. per square inch Date.....
Artesian water is controlled by..... (Cap, valve, etc.)

(9) **WELL TESTS:** Drawdown is amount water level is lowered below static level
Was a pump test made? Yes [ ] No [ ] If yes, by whom?.....
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test 4-11-80
Bailer test 20 gal./min. with 4 ft. drawdown after 3 hrs.
Artesian flow..... g.p.m. Date.....
Temperature of water..... Was a chemical analysis made? Yes [ ] No [ ]

(10) **WELL LOG:** A

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Sandy soil some water at 30'	0	35
light Brown clay some sand no water	35	50
light Brown clay fairly coarse sand water	50	65
less clay coarse sand water	65	75
coarse sand small amount of gravel	75	84
Gravel some coarse sand water	84	87

RECEIVED
APR 24 1980
DEPARTMENT OF ECOLOGY
CENTRAL REGION

Work started 4-7, 19 80 Completed 4-14, 19 80

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME GENE THOMAS (Person, firm, or corporation) (Type or print)

Address RT1 BOX 1269 GRANGER

[Signed] R. Gene Thomas (Well Driller)

License No. 867 Date 4-15, 19 80

(USE ADDITIONAL SHEETS IF NECESSARY)

APPENDIX B

Slug Test Data

Hornby Dairy MW-1

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
60	10.57	1.57	.8051282
120	10.35	1.35	.6923081
190.8	10.05	1.05	.5384616
243	9.88	0.88	.4512822
300	9.71	0.71	.3641027
363	9.57	0.57	.2923075
483	9.41	0.41	.2102562
540	9.310001	0.31	.158975
601.8	9.24	0.24	.1230767
720	9.149999	0.15	7.692246E-02
840	9.05	0.05	2.564095E-02

UNCONFINED AQUIFER

K= 0.3E-03cm/sec
= 6.5 gpd/ft^2
= 0.1E-04 ft/sec
= 0.9 ft/day

REGRESSION COEFFICIENT = -.9833073

Hornby Dairy MW-2

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
127.2	12.45	5.14	.9809159
280.2	12.24	4.93	.9408396
643.8	11.85	4.54	.8664122
900	11.53	4.22	.8053435
2100	10.55	3.24	.6183206
3300	9.78	2.47	.471374

UNCONFINED AQUIFER

K= 0.2E-04cm/sec
= 0.4 gpd/ft^2
= 0.6E-06 ft/sec
= 0.0 ft/day
0.06

REGRESSION COEFFICIENT = -.9997226

Hornby Dairy MW-3

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
60	8.93	1.42	.9530204
180	8.71	1.20	.805369
300	8.62	1.11	.7449664
600	8.36	0.85	.5704693
900	8.17	0.66	.4429528
1200	8	0.49	.3288588
2400	7.64	0.13	8.724777E-02

UNCONFINED AQUIFER

K= 0.8E-04cm/sec
= 1.6 gpd/ft^2
= 0.2E-05 ft/sec
= 0.2 ft/day

REGRESSION COEFFICIENT = -.9979832

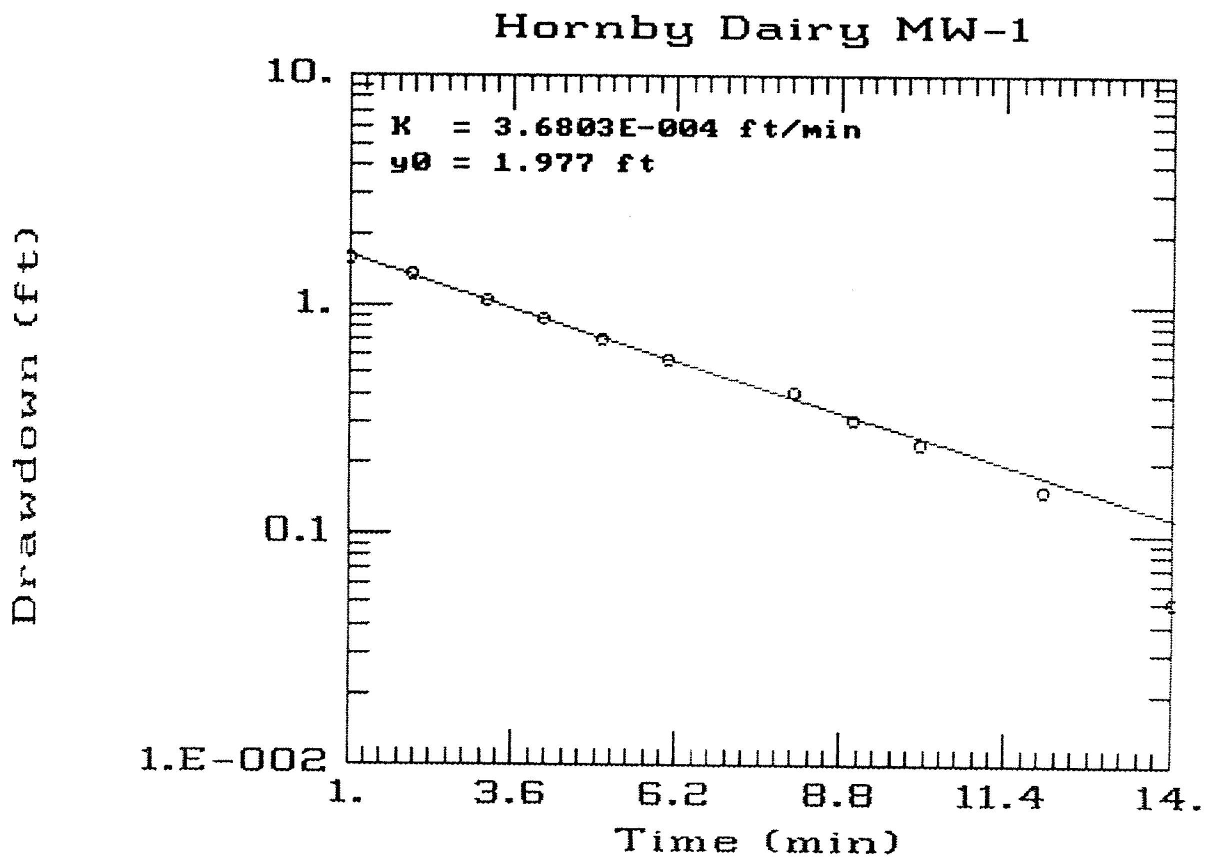
Hornby Dairy MW-4

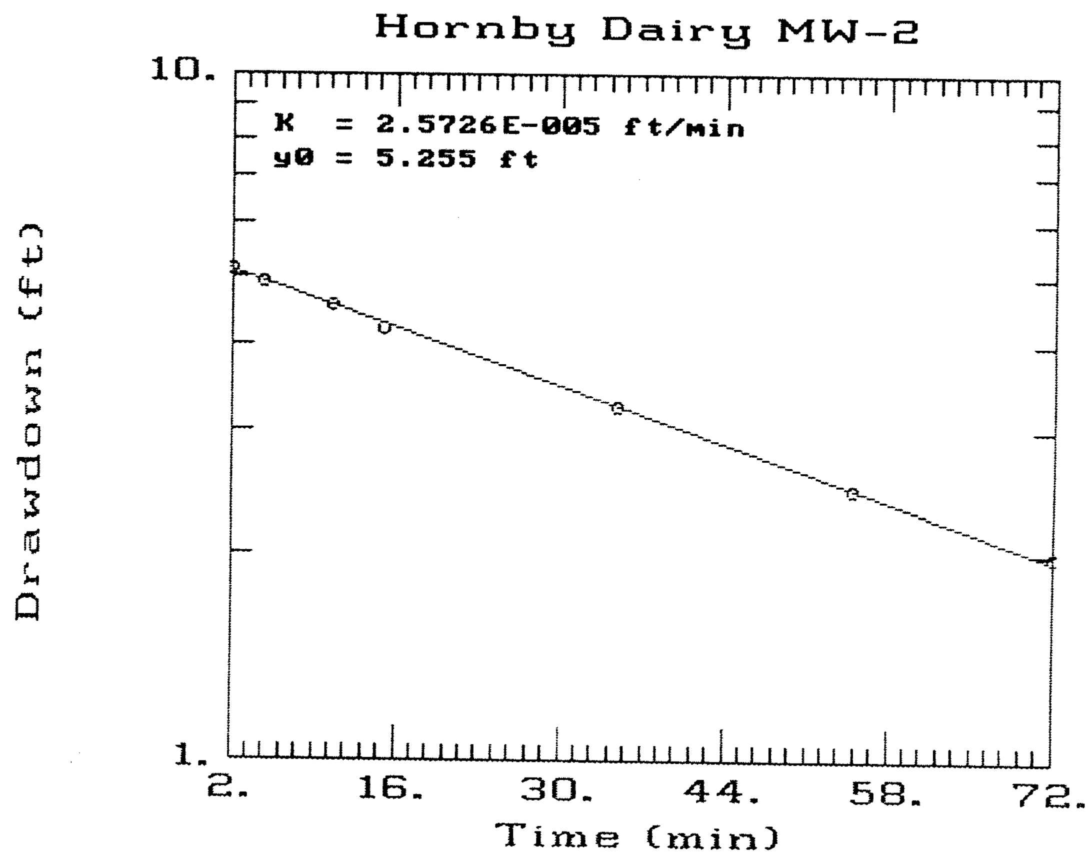
TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
60	9.45	0.99	.9519225
300	9.439999	0.98	.9423065
600	9.32	0.86	.8269226
900	9.229999	0.77	.7403828
1500	9.05	0.59	.5673076
2100	8.939999	0.48	.4615373
2700	8.810001	0.35	.3365397
3300	8.72	0.26	.2499998

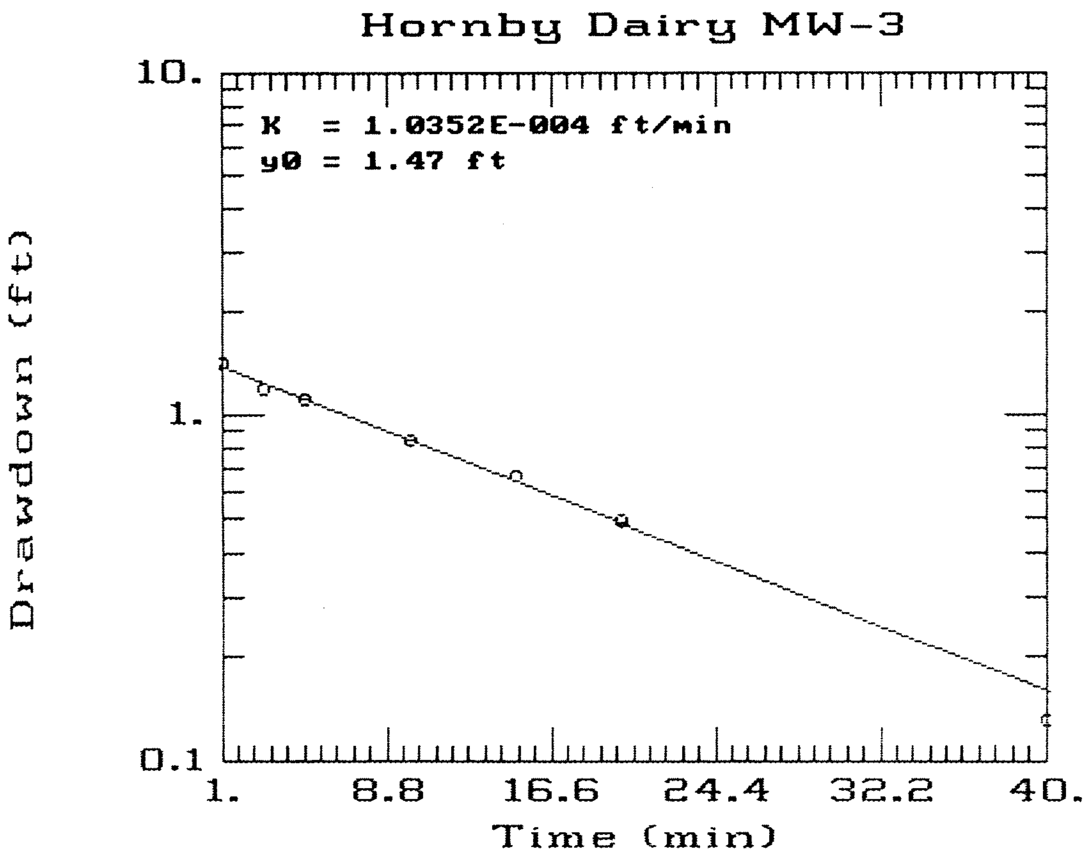
UNCONFINED AQUIFER

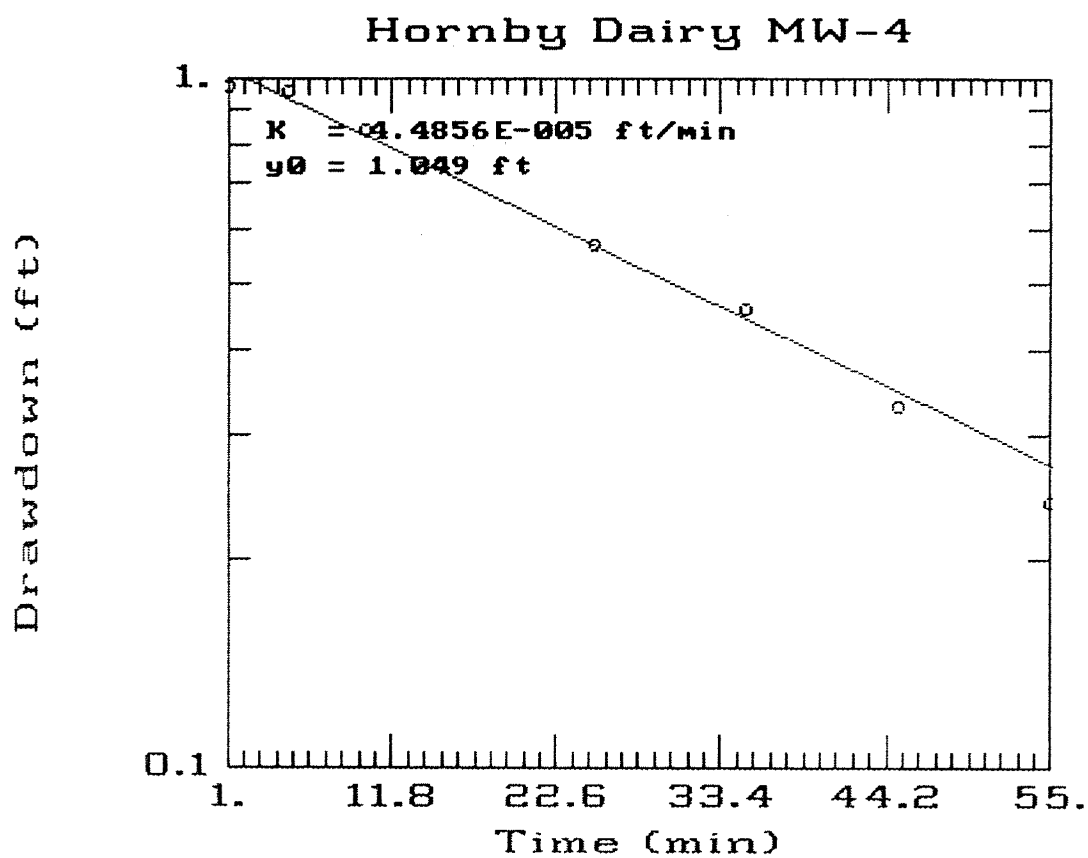
K= 0.3E-04cm/sec
= 0.7 gpd/ft^2
= 0.1E-05 ft/sec
= 0.1 ft/day

REGRESSION COEFFICIENT = -.9962669


Hornby Dairy MW-1
K = 3.6803E-004 ft/min
y0 = 1.977 ft
Drawdown (ft)
10.
1.
0.1
1.E-002
1.
3.6
6.2
8.8
11.4
14.
Time (min)


Hornby Dairy MW-2
K = 2.5726E-005 ft/min
y0 = 5.255 ft
10.
1.
Drawdown (ft)
2.
16.
30.
44.
58.
72.
Time (min)


Hornby Dairy MW-3
K = 1.0352E-004 ft/min
y0 = 1.47 ft
Drawdown (ft)
10.
1.
0.1
1.
8.8
16.6
24.4
32.2
40.
Time (min)



Hornby Dairy MW-4
K = 4.4856E-005 ft/min
y0 = 1.049 ft
Drawdown (ft)
1.
0.1
1.
11.8
22.6
33.4
44.2
55.
Time (min)

APPENDIX C

Water Level Data

Hornby Dairy Lagoon Depth to Water and Water Level Elevations.

Site Name	Date	TOC	X	Y	Depth to Water	Water Elevation
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
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
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
SETTLING POND #1	04/25/90	721.1	NA	NA	1	720.1
SETTLING POND #1	05/02/90	721.1	NA	NA	1.5	719.6
SETTLING POND #1	11/06/90	721.1	NA	NA	2.5	718.6
SETTLING POND #1	01/29/91	721.1	NA	NA	2	719.1
SETTLING POND #2	05/02/90	721.1	NA	NA	0	721
SETTLING POND #2	11/06/90	721.1	NA	NA	1	720.1
SETTLING POND #2	01/29/91	721.1	NA	NA	2	719.1
MAIN LAGOON	04/25/90	720.6	NA	NA	5	715.6
MAIN LAGOON	05/02/90	720.6	NA	NA	5.5	715.1
MAIN LAGOON	07/03/90	720.6	NA	NA	4	716.6
MAIN LAGOON	11/06/90	720.6	NA	NA	5	715.6
MAIN LAGOON	01/29/91	720.6	NA	NA	4	716.6
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
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
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
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

Site Name	Date	TOC	X	Y	Depth to Water	Water Elevation
MW4	11/06/90	717.03	2136446	343715	8.74	708.29
MW4	01/29/91	717.03	2136446	343715	9.51	707.52
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
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
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

NA= Not Applicable