APPENDIX
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Monitoring and Evaluation of Water Quality Under Central Valley Dairy Sites

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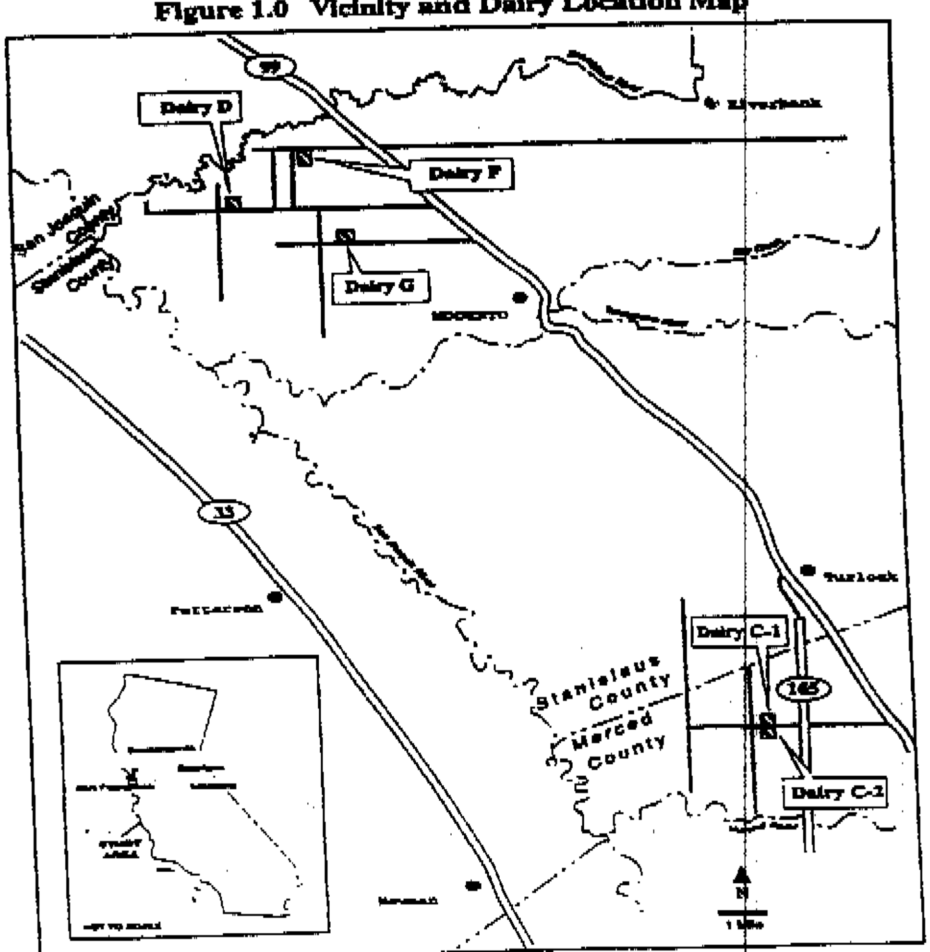
Introduction

The Central Valley Regional Water Quality Control Board received funding from the Federal Statewide Basin Planning Program to evaluate the impact of dairy waste management practices on ground water quality. In June 1993, a drilling company installed forty-four shallow monitoring wells at five cooperating dairies using these funds. Dairies were selected to determine what usually occurs under typical well run dairies. Regional Board staff located monitoring wells in or near the corrals, waste water ponds and fields at the cooperating dairies. The dairies are in Merce-' and Stanislaus Counties near the cities of Modesto and Turlock. Figure 1.0 shows the location of these cooperating dairies. Dairies C-1 and C-2 are in Merced County. Dairies D, F and G are in Stanislaus County.

Figure 1.0 Vicinity and Dairy Location Map



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Profile of Cooperating Dairies

The sizes of the dairies in the study vary between 400 and 900 milk cows. Average dairy size for Stanislaus and Merced Counties is about 350 milk cows. The dairies in the study have been in operation for at least fifteen years. Two of the dairies began in the 1910's but have been modernized and expanded extensively.

Dairy operations are typical of dairies in the two counties. They include the use of corrals, dairy waste water retention ponds and irrigated crop land. Crop land receives dairy waste water. Manure is either flushed from feed or free stall alleys into waste water ponds or scraped from corrals and piled for various uses. At three of the dairies, solids are separated from liquid wastes before the liquid enters the ponds.

Crop land management is also typical of dairies in the region. Oats, barley, wheat, corn and alfalfa are grown for feed in 18 fields on 528 acres surrounding the five dairies. In addition, one dairy grows wine grapes in three fields covering 180 acres.

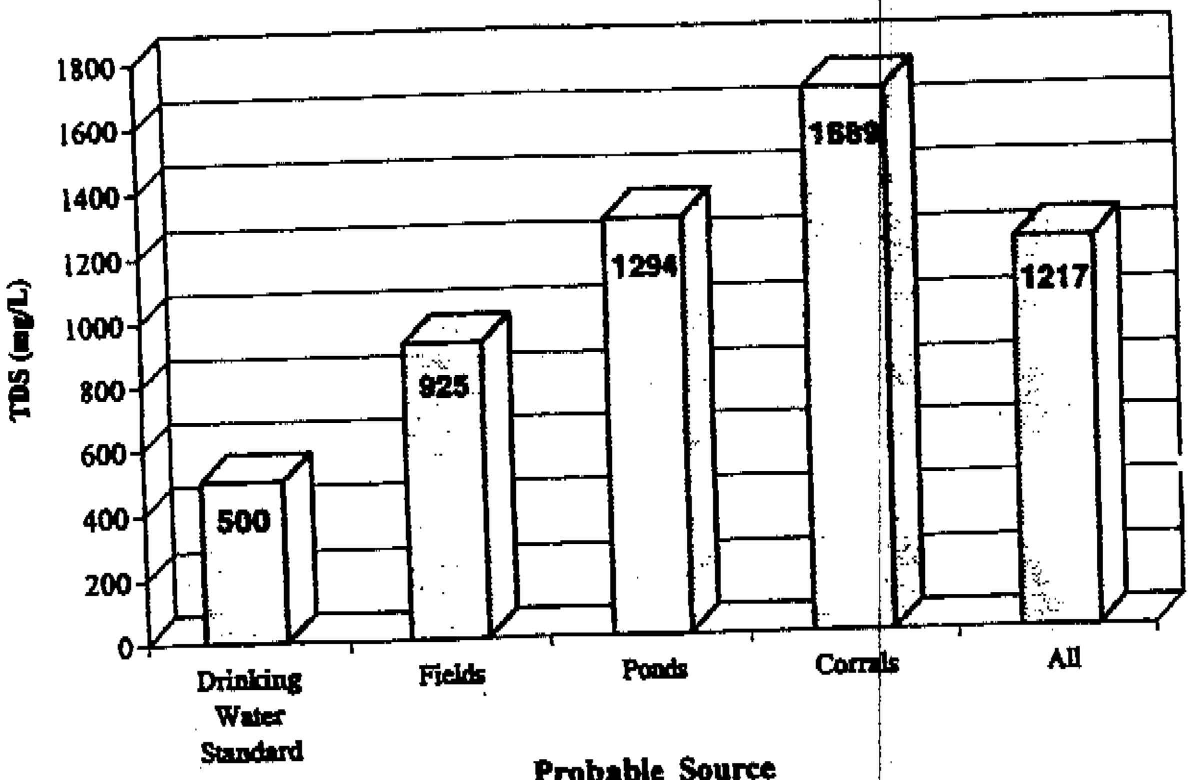
Nearly all the fields received dairy lagoon waste water in 1993. Only three of the twenty-one fields received dry manure solids in 1993. Besides nitrogen in the waste water, every dairy except Dairy F in Stanislaus County added nitrogen in commercial fertilizer to its crop land. The two other dairies in Stanislaus County applied 100 to 112 pounds of commercial nitrogen fertilizer per acre in 1993. The two dairies in Merced County applied from 204 to 306 pounds of commercial nitrogen fertilizer per acre in 1993. Rough calculations of crop nitrogen needs showed that there might be potential to reduce fertilizer applications to some fields. In 1994, the two Merced County dairies and one in Stanislaus County will be using less commercial nitrogen fertilizer. The field managers for these dairies will determine the effect of reducing commercial fertilizer on crop growth and yield.

Soils at the cooperating dairies have sandy and course materials throughout the profile. These soils provide conditions that are generally conducive to the movement of soluble chemicals. Nitrates from the soil profile can migrate into the shallow ground water aquifer under such highly permeable soils. The sandiest soils with the greatest permeability are found at the two Merced County dairies. The Stanislaus County dairies in the study area have higher contents of clays and silts. These soils are less permeable than the soils of the two Merced County dairies. However, the soils at the Stanislaus County dairies are still highly permeable to the movement of soluble chemicals such as nitrates.

Summary of Preliminary Monitoring Results

Monitoring wells were sampled five times: (1) in June 1993 after drilling was completed, (2) in September-October 1993 after the summer crop growing season, (3) in March 1994 after winter rains, (4) in June 1994 which completed one year of sampling and (5) in July-August 1994 to determine changes in concentrations during the growing season. The water table is shallow, ranging in depth from 4 to 25 feet below the surface. The monitoring wells were constructed to collect water representative of the top 10 feet of the shallow aquifer.

Figure 2.0 Concentration by Source of Total Dissolved Solids in Monitoring Wells



Average concentrations of nitrate in monitoring wells varied among the fields, ponds and corrals. Figure 3.0 displays these concentrations for samples collected from June 1993 through August 1994. The fields showed the lowest concentrations averaging 38 mg/l of nitrate nitrogen. The monitoring wells in corrals averaged 74 mg/l of nitrate nitrogen. Nitrate nitrogen near the waste water ponds averaged 45 mg/l of nitrate nitrogen. The average of all monitoring wells in the study was 49 mg/l. All averages were above the drinking water standard of 10 mg/l.

Most drinking water wells in the vicinity of the dairies draw from aquifers greater than 100 feet deep but at least one known nearby domestic well draws from the shallow aquifer of the monitoring wells. Local public health officials during review of new well applications normally limit the use of surface and shallow aquifers for drinking water. They require well seals that prevent surface contamination and well screening below shallow ground water.

Use of waters from the monitoring well aquifer would be limited to more salt tolerant crops. The nitrates from this aquifer would be of benefit to the nitrogen supply of agricultural crops. However, the salt content would most likely need to be diluted to prevent crop damage and loss of production. Nitrates from the shallow ground water of the monitoring wells could be removed by reusing this water on crops. Use of shallow ground water for irrigation would provide a savings in fertilizer and well water pumping expenses. Pumping costs from shallow ground water would be less costly than the expense of pumping from deeper wells that are commonly used for irrigation.

Total dissolved solids (TDS) and electrical conductivity (EC) are measurements of the salinity of water. TDS concentrations ranged from 270 to 4100 mg/l. EC varied from 449 to 6120 µs/cm. For all monitoring wells, the mean TDS was 1217 mg/l and EC was 1911 µs/cm. The ratio of TDS to EC averaged 0.65 but ranged from 0.37 to 0.99.

Acceptable water quality concentrations for salts vary with the intended use. Livestock, irrigated agriculture and drinking water are the primary uses of ground water in the vicinity of the dairies. According to the USGS in the Study and Interpretation of Chemical Characteristics of Natural Waters (1989), some investigators recommended an upper limit of nearly 5,000 mg/l of dissolved solids in water to be used by livestock.

Agricultural water quality goals are 450 mg/l for TDS and 700 µs/cm of EC as recommended by the Food and Agriculture Organization of the United Nations (1989). However, different crops are sensitive to varying levels of salinity. Most fruit and nut crops are sensitive to EC levels from 700 to 1,200 µs/cm. Concentrations above these levels result in reductions in crop yields. But many grasses and some grain crops, such as barley and oats, are more tolerant to higher salt levels in irrigation water. These crops tolerate EC values from 4,000 to 6,500 µs/cm without loss in crop yields.

Primary drinking water standards have not been recommended for TDS. However, the 1962 U.S. Public Health Service secondary drinking water standard states that TDS should not exceed 500 mg/l if other suitable water supplies are available.

Salinity concentrations varied among the monitoring wells in the fields ponds and corrals. Figure 2.0 displays averages for samples collected from June 1993 through August 1994. The monitoring wells in the fields showed the lowest concentrations averaging 925 mg/l of TDS. The monitoring wells in corrals averaged 1689 mg/l of TDS. TDS concentrations in monitoring wells near the waste water ponds averaged 1294 mg/l. Average for all monitoring wells in the study was 1217 mg/l of TDS.

Table 1.0 displays nitrogen concentrations in the monitoring wells. Nitrate as nitrogen ranged from less than the detectable limit of 0.02 mg/l near an irrigation water pond to 250 mg/l under a corral. The average nitrate as nitrogen for the monitoring wells in the dairy study was 49 mg/l. The national drinking water standard for nitrate as nitrogen is 10 mg/l which is equivalent to 45 mg/l of nitrate. High concentrations of nitrates in drinking water have caused methemoglobinemia which is commonly know as blue baby syndrome. Nitrates in irrigation water provide nitrogen as a nutrient to crops.

Monitoring wells away from the corrals and ponds in four of the five dairies had nitrate nitrogen concentrations below 10 mg/l. These low concentrations indicate that the regional shallow aquifer contains low nitrate levels. Lowest concentrations of nitrates generally ranged from 3 to 14 mg/l. These lowest concentrations were at well locations that were minimally affected by the dairy operations. Concentrations in what were expected to be the background wells showed that these particular wells were most likely influenced by dairy operations or other nitrogen sources.

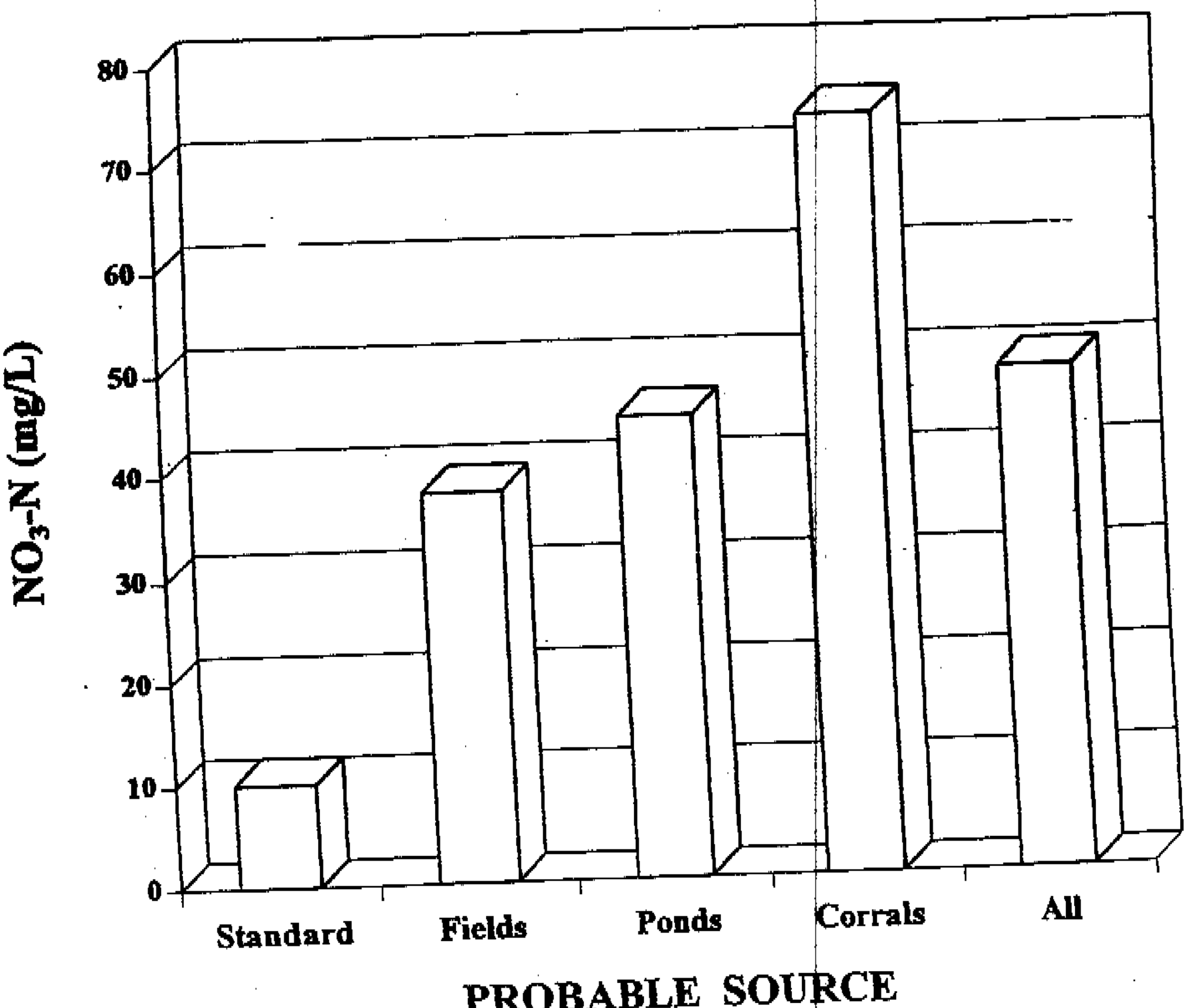
Monitoring wells were located to determine the probable sources of contamination from waste water ponds, corrals or fields. Background monitoring wells were also located upgradient of the dairy operations. Table 1.0 gives a summary of monitoring well water quality for nutrients and salts. EPA and other standard laboratory methods were used. Nitrates (NO_3) and total dissolved solids are of particular interest to ground water quality.

TABLE 1.0 SUMMARY OF MONITORING WELL WATER QUALITY

DAIRY NAME	PO_4-P	NH_3-N	TK-N	NO_2-N	NO_3-N	TOTAL N	TDS	EC
	mg/L							µs/cm
Dairy C-1								
NUMBER OF SAMPLES	7	10	21	8	30	24	24	30
AVERAGE (MEAN)	0.82	0.53	1.04	0.39	86	90	1536	2187
MAXIMUM	2.3		9.6	1.2	250	251	4100	6120
MINIMUM	0.16	<0.05	<1.0	0.02	13	14	390	530
Dairy C-2								
NUMBER OF SAMPLES	7	18	28	9	35	28	28	35
AVERAGE (MEAN)	1.67	13.7	6.5	0.11	50	54	1323	2088
MAXIMUM	5.2	93	57	0.42	140	93	2300	3160
MINIMUM	0.36	<0.05	<0.5	<0.1	0.77	4	420	455
Dairy D								
NUMBER OF SAMPLES	9	17	38	9	41	36	36	41
AVERAGE (MEAN)	1.1	0.53	3.5	0.01	49	52	1276	1966
MAXIMUM	2.8	4.6	38	0.1	200	201	2000	3240
MINIMUM	0.38	0.27	<0.5	<0.1	<0.02	3	370	620
Dairy G								
NUMBER OF SAMPLES	10	14	39	11	50	40	40	50
AVERAGE (MEAN)	1.14	4.5	1.4	0.05	49	50	1060	1648
MAXIMUM	2.4	26	22	0.6	120	120	2200	3270
MINIMUM	0.32	0.07	0.62	<0.02	7.4	8	580	940
Dairy F								
NUMBER OF SAMPLES	12	16	48	13	60	48	48	60
AVERAGE (MEAN)	1.28	0.4	1.1	0.17	30	32	1079	1665
MAXIMUM	3.5	3.8	6.8	0.5	130	130	2200	3140
MINIMUM	0.38	0.1	<0.5	<0.02	1.5	3	270	449
SUMMARY OF DAIRIES								
NUMBER OF SAMPLES	45	75	174	50	216	176	176	216
AVERAGE (MEAN)	1.2	4.4	2.5	0.13	49	52	1217	1860
MAXIMUM	5.2	93	57	1.2	250	251	4100	6120
MINIMUM	0.16	<0.05	<0.5	<0.02	<0.02	3	270	449
STANDARD DEVIATION	0.98	14.4	8.1	5.59	43	43	612	931

Note: Summary of dairy data is from all wells and not the rows above

Figure ~~5-10~~ 3.0 Concentration by Source of Nitrate Nitrogen in Monitoring Wells



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