90-e17

ROCHESTER GROUND WATER QUALITY INVESTIGATION

by
Denis Erickson

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Toxics Investigations/Ground Water Monitoring Section
Olympia, Washington 98504-8711

Water Body No. WA-23-1010 GW
(Segment No. 10-23-18 GW)

November 1990

ABSTRACT

A ground water quality investigation was conducted in the Rochester vicinity to determine if wastewater discharge to an unlined flood channel from the Steelhammer Salmon Farm was affecting ground water. The hydrogeology near the facility consists of a single, highly transmissive aquifer system that is susceptible to contamination. Water quality samples from 22 wells, three surface water stations and wastewater effluent were obtained and tested. Findings of the investigation show that the ground water flow pattern and quality is affected by the facility discharge. At least two feet of mounding was observed in one well located about 200 feet from the discharge channel. Wells downgradient of where the wastewater is ponded in the discharge channel show elevated concentrations of iron and total organic carbon and to a lesser extent total and fecal coliform bacteria, phosphorus and ammonia. Six wells near the ponded area showed iron concentrations that exceeded the secondary Maximum Contaminant Level (MCL) for public water systems. Comparisons with water quality results from 1986 show that ground water quality has deteriorated. Alternative discharge methods should be implemented because continued degradation of ground water is likely if disposal of wastewater to the channel continues. Two public wells are located near the affected area and a potential for their eventual contamination exists.

INTRODUCTION

Facility Description

The Steelhammer Salmon Farm, located about one mile south of the Town of Rochester in Thurston County (Figure 1), is permitted to discharge wastewater to a natural flood channel. The facility started operation in 1977 and an NPDES permit was issued by Ecology in 1981. The average permitted discharge rate is 1.73 million gallons per day (1200 gallons per minute, gpm) and the maximum discharge rate is 3.6 million gallons per day (2500 gpm). The existing permit has expired, but remains in effect, and the development of a revised NPDES permit or coverage under the upland aquaculture general permit is necessary. The water used at the facility is provided by four onsite wells that range in depth from 31 to 75 feet. The flood channel, prior to receiving the wastewater discharge, reportedly was dry except during times of flooding. Presently, water in the channel flows continuously and the length of the channel carrying effluent from the discharge point gradually increased, until in 1989 the channel began discharging to the Black River, about one mile downstream from the facility. The channel has ponded along some reaches; the largest area of ponding occurs where the channel flows under Highway 12 (Figure 1). Nearby landowners and well owners have complained of flooding and of deteriorating ground water quality, especially in the late summer. To date at least five well owners, all located near the discharge channel, have either drilled deeper wells, connected to the Rochester Water Association, or added treatment to their water delivery system in response to deteriorating ground water quality.

Drinking water in the Rochester area is provided solely from ground water. The Town of Rochester operates three public water supply wells. One of these wells (06A02) is located about 1000 feet east of the discharge channel.

Ground water sampling has been conducted intermittently since 1977. Most recently (in 1986), personnel from Ecology's Southwest Regional Office sampled eleven wells near the discharge channel. Specific causes for the ground water quality deterioration were not identified.

The specific objectives of this study were to:

1. Compile and evaluate the existing hydrogeologic and water quality information about the area,

2. Conduct ground water sampling to determine the effects of the Steelhammer Salmon Farm wastewater discharges on ground water quality, and

3 To identify and, to the extent possible, quantify the effects of other potential contamination sources on ground water quality.

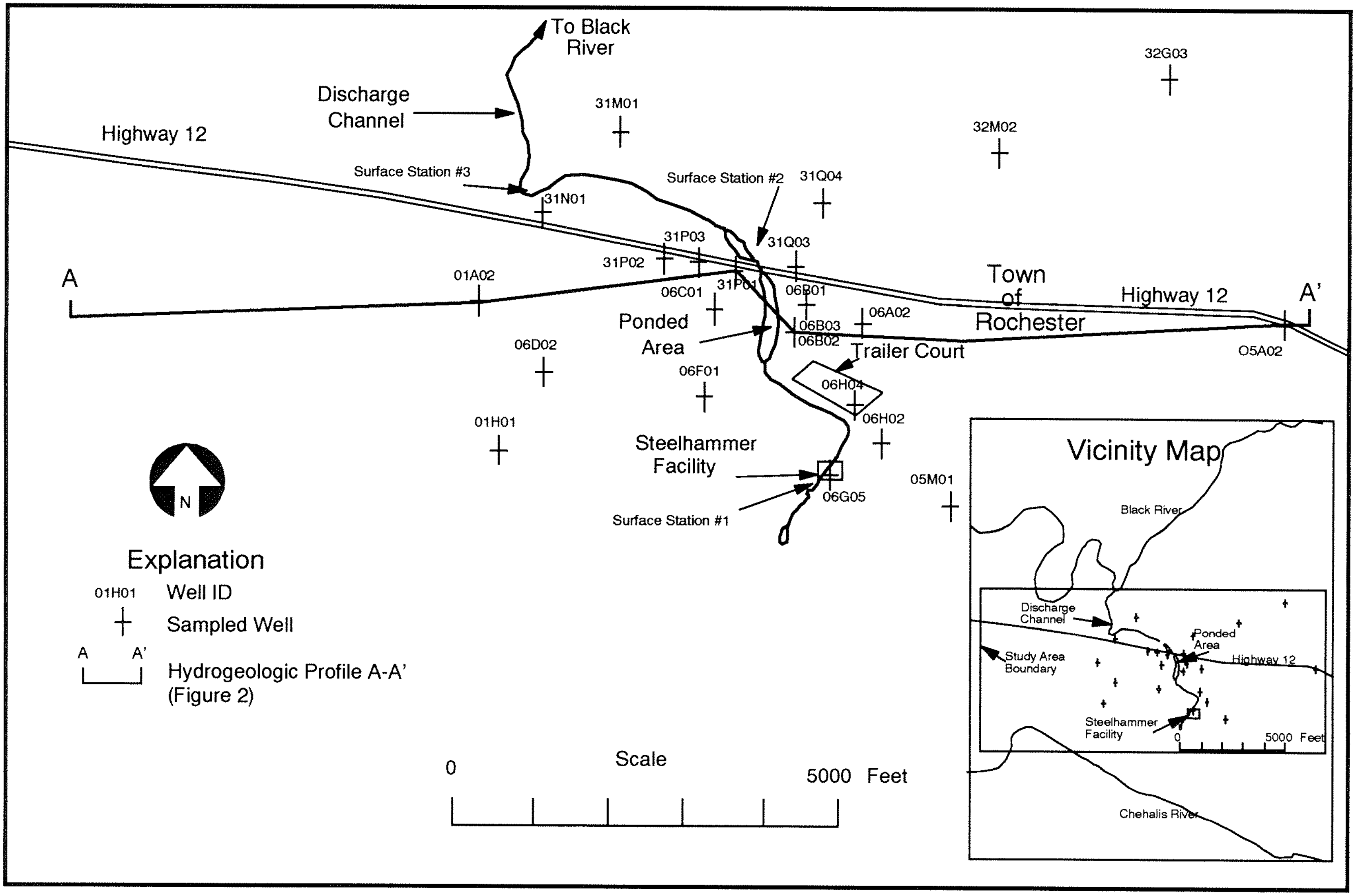

Figure 1: Study Area Location Map

METHODS

Well Inventory

The study area location, shown in Figure 1, extends about one mile east and two miles west of Rochester and is bounded by the Black River on the north and the Chehalis River on the south. An inventory of wells within the study area was prepared from the following sources:

- Department of Ecology Southwest Regional Office (SWRO) files
- A consultant's report evaluating the feasibility of two wastewater discharge alternatives (Fish Pro Inc., 1989)
- Preliminary data from an in-progress Master's thesis (Sinclair and Hirschey, 1989)
- Field visits to the study area
- Thurston County Health Department files

The inventory identified about 140 wells, most of which serve private domestic water supplies, within the study area. However, the inventory is probably incomplete because many wells were drilled before well records were required. Additionally, not all newly drilled wells are reported.

Sampling

Water quality samples were obtained from 22 water supply wells, three surface water locations along the discharge channel, and the wastewater effluent. Sample locations (Figure 1) were selected to fairly represent the ground water quality in the Rochester area with emphasis on the discharge channel. Well characteristics are listed in Appendix A. Four of the wells sampled were public wells and 18 were private domestic wells. Sampling was conducted October 2 to 4, 1989.

Samples were obtained from private and public wells using existing pumps and piping. Sample protocols are listed as follows:

1. A static water level was obtained at each well, access permitting.
2. Wells were pumped until indicator parameters of temperature, specific conductance, and pH stabilized. A minimum of three wells volumes was purged from wells prior to sampling.
3. Samples were obtained as close to the wellhead as possible. All samples were collected from untreated sources.
4. All samples were stored at 4°C prior to delivery to the laboratory.

Water level measurements were obtained from 27 wells and three locations along the flood channel to define the ground water flow pattern and the hydraulic relationship of the discharge channel to ground water. The measurements were made with a Slope Indicator electric probe and were recorded to 0.01 feet. The probe was rinsed with a chlorine solution and deionized water between measurements. Measuring point elevations for the wells and surface water locations were determined by surveyors from the Thurston County Public Works Department. Measurements were recorded to 0.01 feet and are considered accurate to 0.1 feet.

Analysis

The target analytes, methods, and method detection limits are listed in Table 1. Major cations (calcium, magnesium, sodium) and anions (bicarbonate, carbonate, chloride, sulfate) were determined at six wells to define the general ground water quality.

All analytical results were reviewed by staff at the Ecology/US EPA Region X Laboratory in Manchester, Washington. The quality of the data is good and is considered acceptable for use except as qualified below. Low concentrations of iron were detected in procedure blanks and all iron results associated with these blanks within ten times the detection limit (0.01 mg/L) are flagged with a "B" (see Results section, Table 3). Numerous background bacteria were detected in some bacteriological samples and for information purposes are flagged with an "X". All bacteriologic results greater than 200 organisms/100 mL are flagged with an "L" because the values are considered estimates due to potential interference.

In addition, one blind duplicate and one field replicate were tested. Blind duplicates are identical samples obtained simultaneously from the same well but submitted to the laboratory with different sample identification. Blind duplicate results are used to estimate analytical precision and, to some extent, accuracy. Field replicate samples are samples obtained from the same well using the same sampling procedure but collected at different times. Field replicate sample results are used to estimate the overall precision of study results which are a function of analytical accuracy and precision, sampling procedure and environmental effects. Blind duplicate and field replicate results and the relative percent differences (RPDs) are shown in Table 2. RPDs are calculated as the percentage of the difference of two results divided by the mean of the results. In general, the higher the RPD the greater the difference in the results. The RPDs for most parameters for the blind duplicate and field replicate samples are generally less than ten percent. Two exceptions are the RPDs for total organic carbon (TOC), 38 percent for the duplicate, and for total dissolved solids (TDS), 17 percent for the replicate. The cause for the variability of the TOC results is not known. However, the analyst, based on limited testing of unpreserved samples, reported that it may have been related to the shelf life of the bottles and/or the nitric acid preservative. The variability for the TDS replicate results is probably a function of the variation of the ground water quality over time. The RPDs for iron, total coliform, and ammonia for the field replicate are not calculated because these parameters were detected near the level of detection in one sample but were not detected in the other. RPDs for these conditions are not considered representative of the precision of study results. The observed differences of the replicate sample are probably a function of ground water quality changes rather than analytical precision or effects due to sampling procedures.

Table 1. Target Analytes, Test Methods, and Detection Limits.

Analytes	Test Method	Reference	Detection Limit
Field Parameters			
Water Level	Slope Indicator Well Probe	NA	.01 feet
Specific Conductance	Beckman Conductivity Bridge	NA	10 umhos/cm
pH	Beckman pH Meter	NA	0.1 Std Units
Temperature °C	Beckman pH Meter	NA	0.1°C
Conventionals			
Ammonia	#350.1	EPA, 1983	0.01 mg/L
Nitrate/Nitrite-N	#353.2	EPA, 1983	0.01 mg/L
Total Phosphorus	#365.1	EPA, 1983	0.01 mg/L
Total Dissolved Solids	#160.1	EPA, 1983	1 mg/L
Total Organic Carbon	#505	APHA, 1985	0.1 mg/L
Iron, Total Recoverable	#200.7	EPA, 1983	0.01 mg/L
Major Cations and Anions			
Calcium	#200.7	EPA, 1983	0.01 mg/L
Magnesium	#200.7	EPA, 1983	0.03 mg/L
Sodium	#200.7	EPA, 1983	0.03 mg/L
Bicarbonate	#406C	APHA, 1985	1 mg/L
Carbonate	#406C	APHA, 1985	1 mg/L
Chloride	#429	APHA, 1985	0.1 mg/L
Sulfate	#429	APHA, 1985	0.05 mg/L
Bacteriology			
Total Coliform	#909A	APHA, 1985	1#/100 mL
Fecal Coliform	#909C	APHA, 1985	1#/100 mL

Table 2. Rochester Ground Water Quality Assessment-Quality Assurance Results

Sample Type Well ID	Duplicate 31P01	Duplicate 31P01	Duplicate RPD*	Replicate 06G05	Replicate 06G05	Replicate RPD*
Ammonia-N	<0.01	<0.01	--	<0.01	0	--
NO_3+NO_2-N	0	0	0.0	2.4	2.5	-0.4
Total Phosphorus	0	0	0.0	0	0	0.0
Total Organic Carbon	7.5	5	38	8	7.4	4.5
Total Dissolved Solids	79	75	5.2	110	130	-17
Chloride	4.8	4.9	-0.4	5.0	5.0	0.2
Sulfate	3.9	3.9	0.3	4.9	4.9	0.8
Iron-Total Recoverable	1.5	1.5	0.7	<0.005	0	--
Calcium-Total	9.6	9.9	-2.7			
Magnesium-Total	3.0	3.0	-2.0			
Sodium-Total	6	5.9	-3.1			
Bicarbonate as $CaCO_3$	40	40	0.0			
Carbonate as $CaCO_3$	<1	<1	--			
Total Coliform	<1	<1	--	<1	1	--
Fecal Coliform	<1	<1	--	<1	<1	--

*RPD = Relative percent difference of the mean. [(x-y)/((x+y)/2)]X100

-- = RPD calculation not appropriate.

RESULTS

Hydrogeology

The study area is underlain by glacial outwash and alluvial sediments (Wallace and Molenaar, 1961). A west-east hydrogeologic profile (Figure 2) shows the subsurface relationship of the unconsolidated deposits to the discharge channel and selected wells. The glacial outwash is continuous beneath the study area and consists of unconsolidated sand and gravel deposits. Alluvial deposits overlie the outwash deposits on the west side of the study area and consist of mixtures of clay, silt, sand, and gravel. The alluvial sediments are floodplain deposits of the modern Chehalis and Black Rivers. The study area surficial soils consist of loamy sand and gravelly sandy loam east of the Steelhammer facility and silty clay loam west of the facility. The sandier soils are associated with the outwash deposits and the silty clay loam soils are associated with the alluvium and modern floodplain. The discharge channel appears to have been underlain in most locations by silty clay loam (Ness, 1958). Sedimentary bedrock crops out in the low hill on the east side of the study area. Because of the low permeability of the bedrock relative to the outwash and alluvial sediments, it is considered a no-flow boundary for this assessment.

The alluvial and outwash deposits are hydraulically connected and represent a single aquifer system. The aquifer is unconfined and the depth to the water table ranges from 10 to 45 feet. The aquifer thickness is 100 feet about one-and-a-half miles west of the facility (Well 1D01) and about 50 feet thick one mile east of the facility. The thickness of the aquifer beneath the facility is not known because no facility wells penetrate the entire thickness of the aquifer. Two of the production wells at the Steelhammer facility with available well logs are completed at a depth of 62 and 75 feet. One other production well is reportedly completed at a depth of 31 feet (Fish Pro, 1989). The water-table contour map (Figure 3) shows the ground water flow pattern based on water levels obtained October 2 to 4, 1989. The regional ground water flow is toward the west. The hydraulic gradient appears to be fairly steep on the eastern one-third of the study area and flattens on the western two-thirds. Because the aquifer system is unconfined, it is affected by the major drainages: namely, the Black and Chehalis Rivers and Scatter Creek and locally by the discharge channel near the ponded area near Highway 12.

Ground Water Quality

Water quality results for the October samples for conventional parameters and iron are shown in Table 3. Four parameters that were present in the wastewater effluent and the discharge channel were also present in wells adjacent to the discharge channel at concentrations above background. These parameters were ammonia as N, total phosphorus, TOC, and total coliform bacteria. Their distributions in the study area are discussed below.

Ammonia as N was detected in the wastewater effluent at a concentration of 0.68 mg/L and in the discharge channel at two of the three surface water sampling locations at concentrations of 0.8 and 0.13 mg/L. The concentrations in the discharge channel decreased downstream of the

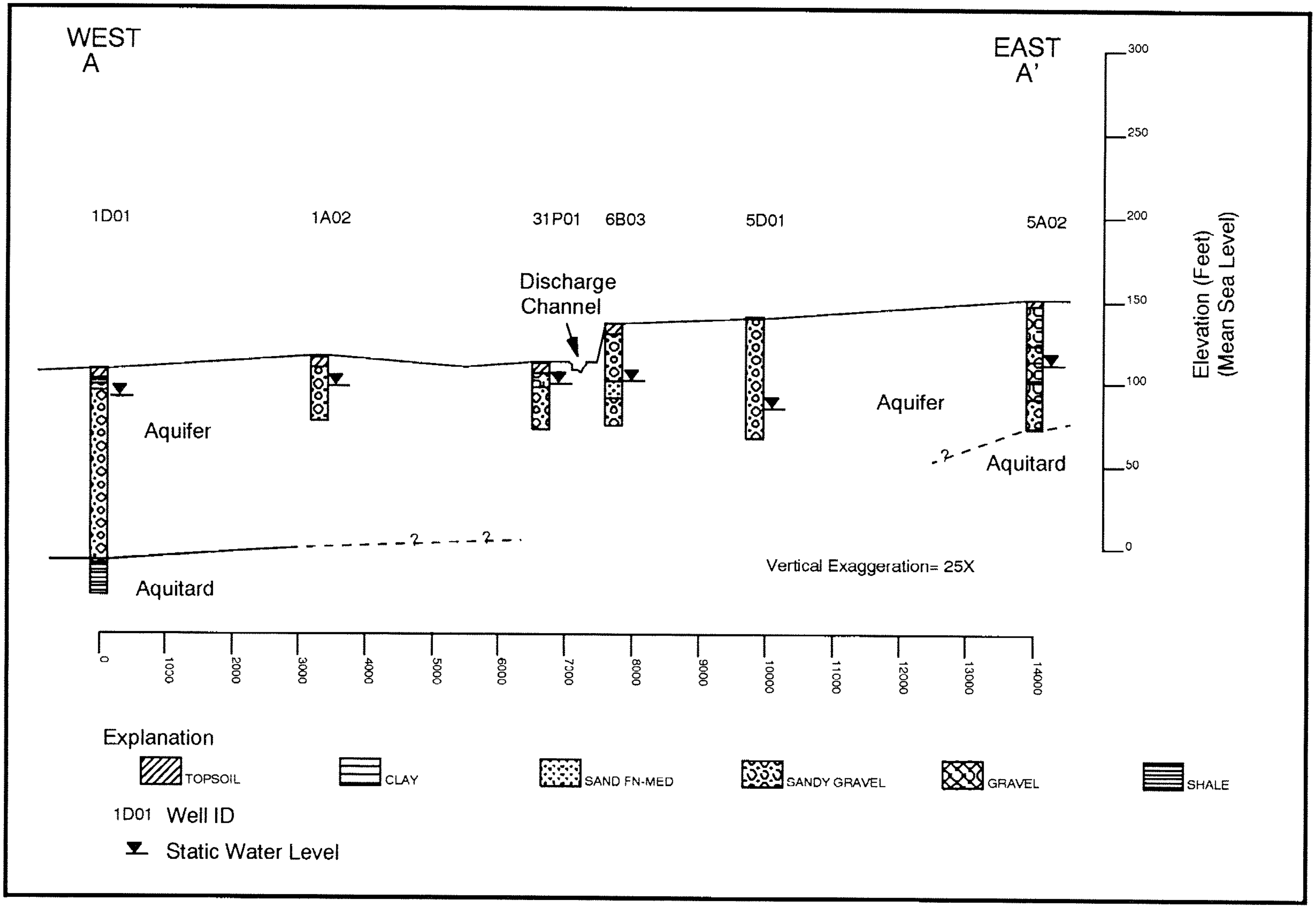

Figure 2: Hydrogeologic Profile A-A'

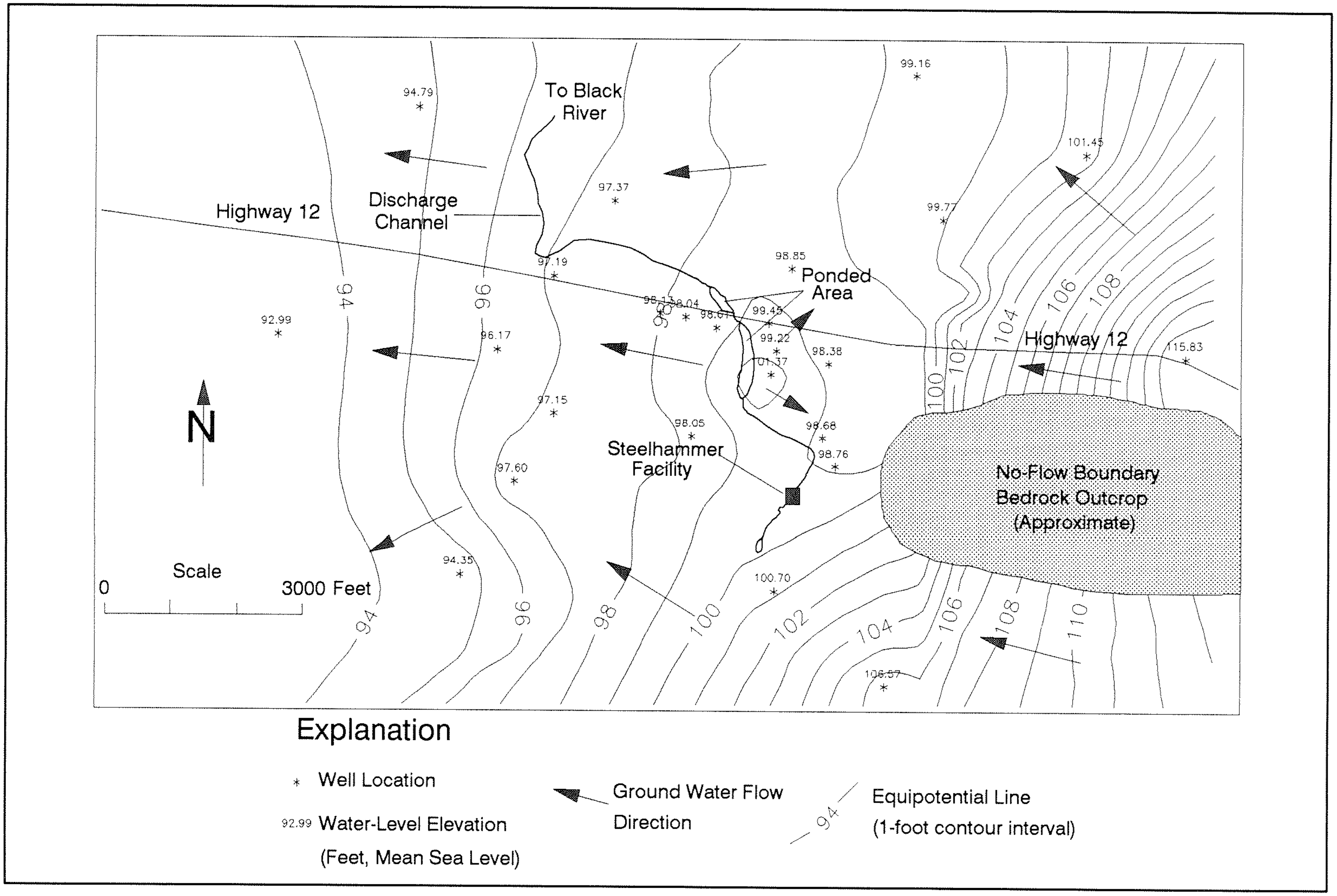

Figure 3: Water-Table Contour Map, October 1989

Table 3. Rochester Ground Water Quality Assessment-Ground Quality Results, October 1989. (Units=mg/L unless shown otherwise.

Sample Locations	Ammonia-N Q	NO_3+NO_2-N Q	Total Phosphorus Q	Total Organic Carbon Q	Total Dissolved Solids Q	Chloride Q	Sulfate Q	Iron Tot-Rec Q	Total Coliform Q (#/100mL)	Fecal Coliform Q (#/100mL)
Private Wells										
Effluent	0.68	2.2	0.27	6.0	110	5.3	4.9	0.01B	270 XL	<1
Surface Station #1	0.81	2.3	0.33	10.1	160	5.4	5.0	0.05	390 L	200
Surface Station #2	0.13	2.4	0.23	5.2	100	5.3	5.0	0.01B	220 XL	23
Surface Station #3	<0.01	2.3	0.20	3.3	98	5.3	4.9	0.02B	150 X	9
06H02	<0.01	2.4	0.03	6.9	130	4.9	4.5	0.03	<1	<1
05M01	<0.01	2.5	0.02	5.7	160	5.2	4.4	0.14	<1	<1
32M02	<0.01	2.2	0.02	5.6	130	4.0	4.1	0.02	1	<1
31P02	<0.01	0.9	0.03	8.8	86	4.9	4.7	0.87	<1	<1
06F01	<0.01	2.4	0.03	8.1	100	4.5	4.2	0.03B	<1	<1
01H01	<0.01	2.4	0.03	10.2	89	4.7	4.1	0.07	<1 X	<1
06D02	<0.01	2.2	0.03	3.3	110	4.4	4.3	0.01B	1	<1
01A02	<0.01	5.3	0.03	3.5	100	4.6	4.4	0.03B	<1	<1
31N01	<0.01	0.1	0.02	4.7	73	5.5	4.2	0.26	<1	<1
31Q04	<0.01	2.2	0.02	8.5	100	5.1	4.0	0.02B	<1 X	<1
31M01	<0.01	0.6	0.02	7.5	140	4.9	4.5	0.44	<1	<1
06B03	0.01	<0.01	0.04	10.5	130	5.5	2.5	0.40	7 X	1
06B01	<0.01	0.3	0.02	9.9	84	5.4	2.8	0.33	<1 X	<1
31Q03	<0.01	0.2	0.02	7.1	140	5.3	3.1	0.33	<1	<1
31P03	<0.01	0.4	0.02	8.0	120	4.8	4.1	0.21	<1	<1
06C01	<0.01	0.1	0.21	8.0	74	4.4	2.7	4.77	<1	<1
31P01	<0.01	0.1	0.07	7.5	79	4.8	3.9	1.48	<1	<1
31P01	<0.01	0.1	0.07	5.1	75	4.9	3.9	1.47	<1	<1
Public Wells										
06G05	<0.01	2.4	0.03	7.7	110	5.0	4.9	ND	<1	<1
06G05	0.01	2.5	0.03	7.4	130	5.0	4.9	0.01	1	<1
06H04	<0.01	3.7	0.03	7.0	150	6.1	5.2	0.03	<1	<1
06A02	<0.01	2.7	0.02	4.5	74	5.0	3.9	0.01B	<1	<1
05A02	<0.01	1.5	0.02	5.0	91	4.3	4.5	0.01B	<1 X	<1
32G03	<0.01	2.7	0.02	6.0	100	4.4	3.8	0.94	<1	<1

Q= Qualifiers as defined below.
B= Analyte detected in procedure blank.
L= Total plate count greater than 200.
X= Many background organisms.

facility. Ammonia as N was detected in two wells at the detection limit, 0.01 mg/L. Both of these wells were located adjacent to the discharge channel. One well was a Steelhammer Salmon Farm production well (06G05) and the other well (06B03) was located next to ponded area south of Highway 12.

The concentration of total phosphorus in the effluent was 0.27 mg/L and in the discharge channel ranged from 0.2 to 0.33 mg/L. The distribution of total phosphorus concentrations in the study area is shown in Figure 4. Background concentrations for total phosphorus upgradient of Rochester appear to range from 0.02 to 0.03 mg/L. Three wells show elevated concentrations of 0.04, 0.07, and 0.21 mg/L. All three wells were located near the ponded area south of Highway 12.

The distribution of TOC concentrations in the study area is shown in Figure 4. Background concentrations upgradient of Rochester appear to range from about 5 to 6 mg/L. TOC was present in the effluent at 5.0 mg/L and in the discharge channel at concentrations that ranged from 3.3 to 10.1 mg/L, decreasing downstream of the facility. Elevated concentrations of 8 to 10 mg/L occur downgradient of the ponded area near Highway 12. However, not all elevated concentrations of TOC are associated with the channel. For example, one well located about 1000 feet upgradient of the ponded area showed a TOC concentration of 8.5 mg/L. Unfortunately, analytical accuracy and precision for TOC was about 38 percent (see Quality Assurance section) which limits the certainty of conclusions that can be made about TOC distributions.

Total coliform bacteria were present in the effluent at a concentration of 270 organisms/100 mL. Total coliforms were also present in the discharge channel at concentrations that ranged from 150 to 390 organisms/100 mL. Total coliforms were detected in four wells. Two of the wells were adjacent to the discharge channel. One of these wells showed a concentration of 7 organisms/100 mL. One well was a Steelhammer production well. Fecal coliforms were not present in the wastewater effluent but were present in the discharge channel at concentrations that ranged from 9 to 200 organisms/100 mL. Fecal coliforms were detected in one well. This well is located adjacent to the discharge channel and was the same well that showed total coliforms at a concentration of 7 organisms/100 mL.

Two other parameters, iron (total recoverable) and nitrate-nitrite as N, have concentration distributions (Figure 5) that appear to be affected by the discharge channel and are discussed below. Iron was present in the effluent and the discharge channel at concentrations of about 0.01 to 0.05 mg/L. Upgradient concentrations of iron generally ranged from 0.01 to 0.02 mg/L with the exception of one upgradient well, 32G03, which showed a concentration of 0.94 mg/L. Seven wells in the vicinity of the ponded area near Highway 12 showed substantially elevated concentrations of iron that ranged from 0.2 to 4.7 mg/L.

Nitrate-nitrite as N distribution shows a different pattern. Nitrate-nitrite as N was present in the effluent at 0.68 mg/L and in the discharge channel at concentrations ranging from less than the detection limit, 0.01 mg/L, to 0.81 mg/L. The concentration in the discharge channel decreased

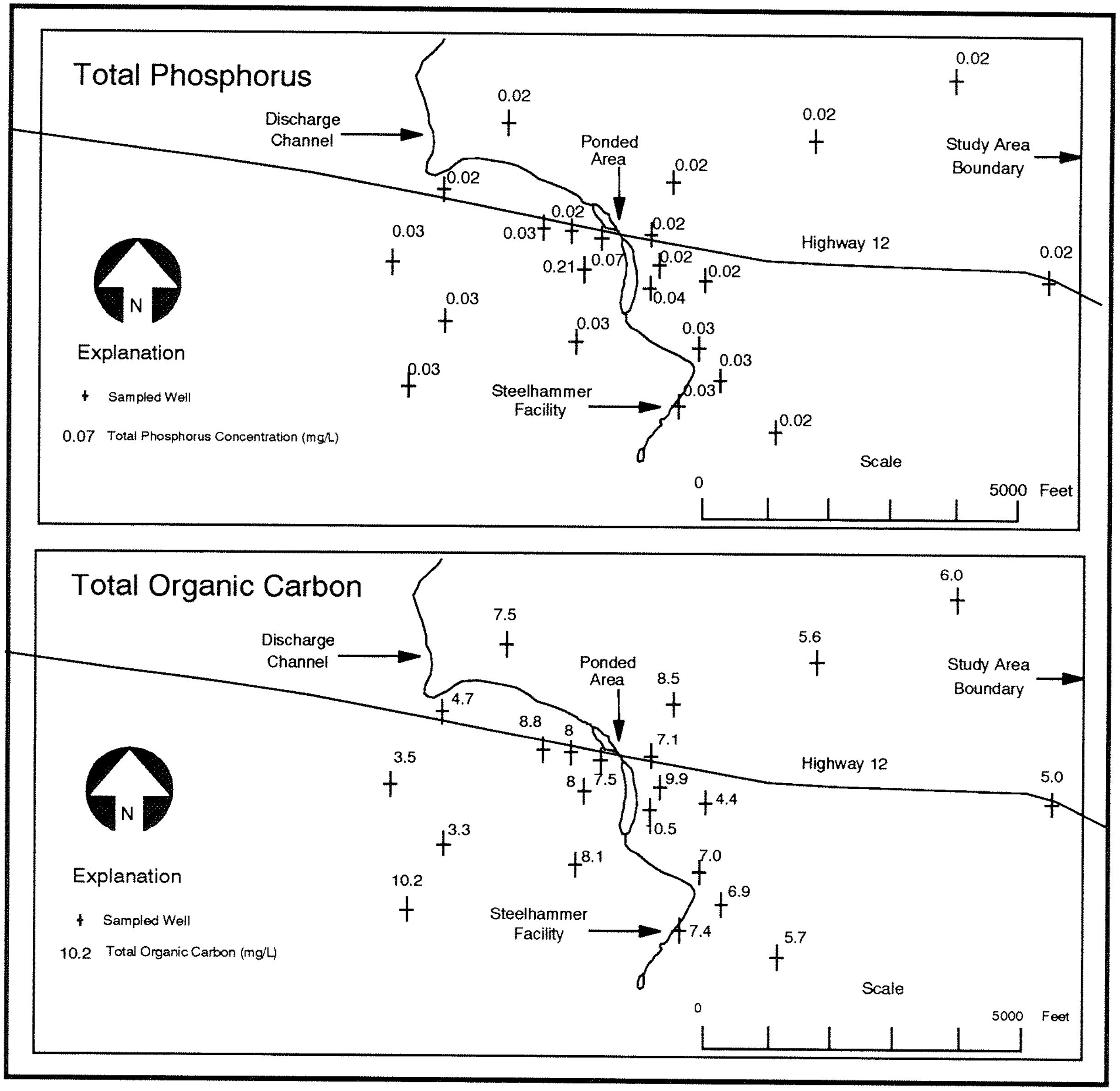

Figure 4. Total Phosphorus and Total Organic Carbon (TOC) Concentrations (mg/L)

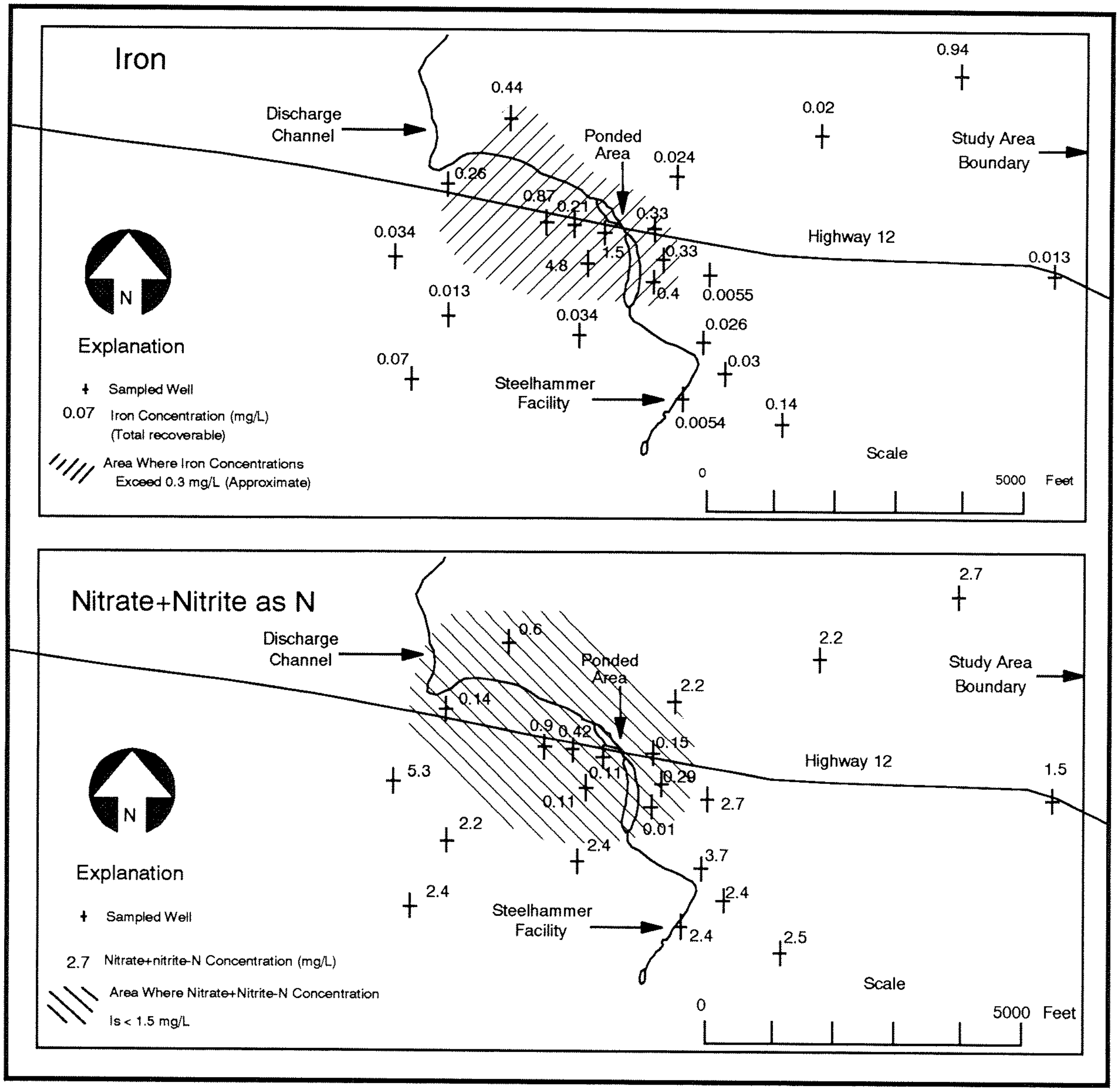

Figure 5. Iron and Nitrate-Nitrite as N Concentrations (mg/L)

downstream of the facility. Nitrate-nitrite as N concentrations in wells ranged from less than the detection limit (0.01 mg/L) to 5.3 mg/L. Upgradient concentrations ranged from 2 to 3 mg/L. Concentrations less than 1 mg/L occurred in the area immediately downgradient of the ponded area near Highway 12. The maximum concentration, 5.3 mg/L, occurred at a well (01A02) at the far west side of the study area.

The other parameters in the study--TDS, chloride, and sulfate concentrations--appear to be uniformly distributed across the study area. Also, the concentrations of these parameters in the effluent do not vary significantly from those naturally occurring in study area ground water. TDS concentrations in ground water range from 70 to 160 mg/L. The TDS concentration of the effluent was 75 mg/L. Chloride concentrations in ground water ranged from 4.0 to 6.1 mg/L. The effluent concentration was 5.3 mg/L. The sulfate concentration in ground water ranged from 2.5 to 5.1 mg/L. The concentration in the effluent was 4.9 mg/L.

Table 4 shows the major cation and anion results. Ground water in the study area is dominated by calcium, sodium and bicarbonate ions. Results in Table 4 have been converted to milliequivalents per liter to compare the charge balance, the sum of anions and cations, for each analyses. The sum of cations and anions should be about equal if all important ions have been adequately identified. The analyses listed in Table 4 show reasonable agreement of anion and cation sums.

DISCUSSION

The discharge from the Steelhammer facility has affected the ground water flow pattern and the ground water quality. The effects are most apparent in ground water near the ponded area near Highway 12 and are discussed below.

Effects on the Ground Water Flow Pattern

The water level in the discharge channel as determined at the three surface water stations is about ten feet above the water table. Therefore the channel provides a downward driving force for water and dissolved contaminants. The water table contour map (Figure 3) shows a distortion of the equipotential lines, in particular the 99- and 100-foot contours, in the vicinity of the ponded area of the channel near Highway 12. Leakage from the channel is likely occurring which results in localized mounding of the water table. It appears that the leakage rate from the channel is enough to cause mounding, but it would also suggest that there may not be a direct hydraulic connection (i.e. the entire thickness of sediments underlying the channel may not be saturated). The water table is mounded about two feet at one well (06B02) about 200 feet from the channel. Unfortunately, the amount of mounding and the degree of hydraulic connection with the channel and the water table can only be estimated with the existing data.

Table 4. Rochester Ground Water Quality Assessment-Major Cations and Anions, October 1989.

	01H01		31P03		06C01		31P01		31P01		06A02		32G03	
	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	meq/L	mg/L	eq/L	mg/L	meq/L	mg/L	meq/L
Cations:														
Sodium	5.97	0.260	5.84	0.254	5.82	0.253	5.7	0.248	5.88	0.256	6.04	0.263	5.6	0.244
Potassium	0.43	0.011	0.66	0.017	0.62	0.016	0.69	0.018	0.66	0.017	0.67	0.017	1	0.016
Calcium	10.2	0.509	10.1	0.504	9.93	0.496	9.59	0.479	9.85	0.492	10.0	0.491	10.0	0.499
Magnesium	3.47	0.285	2.98	0.245	2.88	0.237	2.98	0.245	3.04	0.250	2.91	0.235	3	0.239
Total=		1.065		1.020		1.001		0.989		1.014		1.006		0.998
Anions:														
Carbonate as $CaCO_3$	ND	0.000	ND	0.000	ND	0.000	ND	0.000	ND	0.000	ND	0.000	ND	0.000
Bicarbonate as $CaCO_3$	33	0.660	39	0.780	41	0.820	40	0.800	40	0.800	30	0.600	30	0.600
Sulfate	4.11	0.086	4.1	0.085	2.65	0.055	3.91	0.081	3.9	0.081	3.89	0.081	3.76	0.078
Chloride	4.67	0.132	4.79	0.135	4.43	0.125	4.84	0.137	4.86	0.137	4.95	0.140	4.44	0.125
NO3 + NO2-N	2.38	0.170	0.42	0.030	0.11	0.008	0.11	0.008	0.11	0.008	2.68	0.191	2.74	0.196
Total=		1.047		1.030		1.008		1.025		1.026		1.012		0.999

ND = Not detected

meq/L = milliequivalents per liter

Effects on Ground Water Quality

Most of the water quality effects of the wastewater discharge appear to be related to the ponded area south of Highway 12. Six parameters ammonia as N, total phosphorus, total organic carbon, iron (total recoverable), and total and fecal coliform bacteria are elevated relative to upgradient conditions. Concentrations of nitrate+nitrite as N are lower than background conditions in this area. Two of the parameters that show elevated concentrations, iron and total coliforms, have drinking water standards for public supplies (Department of Health, 1989). The secondary MCL for iron is 0.3 mg/L. Six wells in the vicinity of the ponded area showed iron concentrations that exceeded the secondary MCL. The hachured area on Figure 5 shows the approximate area where iron concentrations exceeded 0.3 mg/L. This area coincides approximately with the area that is downgradient of the ponded area near Highway 12 (Figure 3). The elevated iron concentrations most likely are related to the disposal of effluent to the discharge channel. The ponding of nutrient-rich water results in the seasonal deposition of organic detritus on the channel bottom. Decomposition of this organic material depletes available oxygen and the dissolution of the organics lowers the pH of the ground water. These reducing and more acidic conditions dissolve additional ferrous (Fe^{++}) iron which then moves with the ground water. The process is similar to changes in ground water associated with natural bogs (Hynes, 1972). This explanation is consistent with the observation that nitrate-nitrite as N concentrations appear to be lower in this same area. Under reducing conditions nitrate would be reduced (denitrified) to less oxidized forms such as nitrogen gas.

Total and fecal coliform bacteria are used to identify water that may be contaminated by human or animal wastes. The primary MCL for total coliform bacteria for public wells is 1 organism/mL. Primary MCLs are established based on the potential for human health effects. One well, located near the channel, had 7 organisms/100 mL. Three other wells had total coliform counts of 1 organism/100 mL. One of these three wells was located near the discharge channel. The well with 7 organisms/100 mL also had elevated concentrations of iron (0.34 mg/L), phosphorus (0.04 mg/L), and ammonia (0.01 mg/L). The contamination observed in this well appears to be related to the discharge channel. Another possible source of contamination could be septic tank effluent in which coliform bacteria, ammonia and phosphorus are also present. However, if septic tank effluent were the source, elevated chloride concentrations would be expected but were not observed.

The sources for the occurrences of total coliform bacteria in the other two wells (06D02 and 32M02) are unknown. No other parameters showed elevated concentrations in these two wells.

Changes in Water Quality Since 1986

Eight wells and one surface water location sampled in October 1989 for this assessment also had been tested for some of the same parameters by Ecology's Southwest Regional Office on September 3, 1986. These results are compared in Table 5. Most of the parameters show little difference from 1986 and 1989 sampling events. However, iron and phosphorus concentrations appear to have increased. Iron concentrations increased in all wells, but the increases in the two

Table 5. Rochester Ground Water Quality Assessment-Results for 1986 and 1989. (Units= mg/L)

Sample Location	Date	Ammonia-N	NO_3+NO_2-N	Total Phosphorus	Chloride	Sulfate	Iron (Total Recoverable)	Calcium	Magnesium	Sodium	Bicarbonate as $CaCO_3$
31P02	09/03/86	<0.01	0.5	0.02	5.1	4.0	<0.005	7.3	3.2	6.0	47
31P02	10/03/89	<0.01	0.9	0.03	4.9	4.7	0.873				
31N01	09/03/86	<0.01	0.16	0.02	4.8	3.4	0.009	6.4	2.5	5.6	37
31N01	10/03/89	<0.01	0.14	0.02	5.5	4.2	0.262				
06B03	09/03/86	0.01	<0.01	0.03	5.4	2.0	0.059	8.6	3.5	6.9	57
06B03	10/04/89	0.01	<0.01	0.04	5.5	2.5	0.399				
06B01	09/03/86	<0.01	0.21	0.02	4.9	3.0	0.238	7.5	3.2	5.9	48
06B01	10/04/89	<0.01	0.29	0.02	5.4	2.8	0.331				
31Q03	09/03/86	<0.01	0.12	0.02	5.6	4.3	<0.005	8.6	3.4	6.4	50
31Q03	10/04/89	<0.01	0.15	0.02	5.3	3.1	0.326				
06C01	09/03/86	<0.01	0.16	0.02	4.4	3.1	0.013	6.6	2.6	5.5	39
06C01	10/04/89	<0.01	0.11	0.21	4.4	2.7	4.77	9.9	2.9	5.8	41
Surface Station #2	09/03/86	0.03	1.7	0.17	5.1	5.2	<0.005	7.0	3.2	6.1	40
Surface Station #2	10/03/89	0.13	2.4	0.23	5.3	5.0	0.013				
06H04	09/03/86	<0.01	3.1	0.03	5.9	5.0	0.017	8.0	2.9	6.8	35
06H04	10/02/89	<0.01	3.7	0.03	6.1	5.2	0.026				
06A02	09/03/86	<0.01	2.3	0.02	5.0	4.4	<0.005	6.7	2.8	6.0	34
06A02	10/03/89	<0.01	2.7	0.02	5.0	3.9	0.0055	9.8	2.9	6.0	30

upgradient wells (06H04 and 06A02) were small. The increases in wells downgradient of the discharge channel are much greater. The maximum concentration change was observed at well 06C01; the iron concentration increased from 0.013 mg/L in 1986 to 4.77 mg/L. Also total phosphorus increased in three wells. All three wells are downgradient of the ponded area. The changes were not particularly large with the exception of one well, 06C01, which showed a change from 0.02 mg/L in 1986 to 0.21 mg/L in 1989.

Other Potential Sources of Contamination

A secondary objective of this study was to assess the affects of other potential sources of contamination to ground water in the study area. At the outset of the study, two potential sources were identified: 1) effluent from septic tanks, in particular from the Tanglewood Mobile Home Park located adjacent to the channel, and 2) runoff from the pole yard located on the north side of Rochester. Reportedly, runoff from the pole yard enters a ditch which eventually discharges to the flood channel. The ditch is dry most of the year and flows only after rainfall events. Because the flow is intermittent, it was not judged to be a significant contributor to ground water degradation and was not sampled for this study.

The mobile home park consists of 62 mobile home units. Two or three units, depending on their location in the park, share a common septic tank.

Based on the ground water flow direction shown in Figure 3, only one well, the trailer court water supply well (06H04), is located downgradient of part of the trailer court. Unfortunately the trailer court is also downgradient of the ponded area near Highway 12 and, therefore, may not be a good measure of potential loading from septic tanks. The nitrate+nitrite as N (3.7 mg/L), chloride (6.1 mg/L), and total dissolved solid (150 mg/L) concentrations, parameters associated with septic tank effluent, are slightly elevated above background concentrations. However, these slight elevations do not, at present, represent a significant threat to ground water quality.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions of the Rochester ground water quality assessment are summarized as follows:

1. The hydraulic head in the discharge channel is about ten feet higher than the water table, therefore, the potential exists for the downward migration of constituents from the channel to ground water. Water levels in wells near the channel suggest that leakage from the channel near the ponded area next to Highway 12 is resulting in at least two feet of mounding beneath the channel. However, the data are not adequate to define accurately the degree of hydraulic connection between the channel and the water table.

2. The wastewater discharge from the Steelhammer Salmon Farm has affected ground water quality particularly in the vicinity of the ponded area near Highway 12. Parameters that

show elevated concentrations in ground water are total phosphorus, total organic carbon, iron (total recoverable), and total coliform bacteria. Nitrate+nitrite as N concentrations in this area are lower than background concentrations.

3. Iron exceeded the secondary MCL, 0.3 mg/L, in eight of the wells tested. The concentrations in the eight wells ranged from 0.33 to 4.77 mg/L. Six of these wells are near the ponded area near Highway 12. The mobilization of iron is due to the reducing and probably acidic conditions that exist beneath the discharge channel.

4. Ground water quality has deteriorated since September 1986. Iron concentrations have increased substantially in all six wells sampled in 1986 and 1989 downgradient of the ponded area near Highway 12. Also total phosphorus concentrations have increased slightly in two wells and substantially in one other well.

5. It is likely that as long as effluent continues to be discharged to the channel the extent of the contamination will continue to increase. Two public wells, one of the Rochester wells (06A02) and the trailer court well (06H04), appear to be downgradient of the mounded area (Figure 3). The hydraulic gradient between the ponded area and the wells may be higher than shown on Figure 3 if pumping water levels are used.

Recommendations based on the findings of the Rochester ground water assessment are listed as follows:

1. The discharge of effluent to the unlined flood channel should be discontinued and an alternative method of wastewater disposal at Steelhammer Salmon Farm should implemented. The selected alternative should minimize or eliminate the adverse effects on ground water quality.

2. Additional studies should be conducted to determine the potential threat to the two public wells located near the ponded area. Tasks that should be conducted are listed as follows:

   <u>Task 1</u>. Conduct water quality sampling at the two public wells near the ponded area to determine if degradation has occurred since October 1989. The sampling should continue quarterly until an alternate discharge method is implemented.

   <u>Task 2</u>. Evaluate the potential for additional degradation of ground water quality for the two public wells located near the ponded area. The following subtasks should be conducted for this evaluation:

      Subtask 2a. Obtain and evaluate all pump test or bailer test information from the two public wells and other wells in the vicinity to determine the spatial distribution of transmissivity, the ease that water moves through the aquifer.

Subtask 2b. Quantify the amount of mounding of the water table beneath the ponded areas by installing monitoring wells adjacent to the channel and obtaining water levels in these wells.

Subtask 2c. Obtain pumping water levels and average and peak pumping rates for the public wells.

Subtask 2d. Select and calibrate a ground water flow model to simulate the potential affects on the two public wells.

Task 3. Define the seasonal variation of the ground water flow pattern by measuring water levels in the 27 wells measured in October 1989 quarterly for one year.

3. Conduct follow-up sampling after an alternate discharge method is implemented to document the improvement of ground water quality.

REFERENCES

APHA *et al.*(American Public Health Association, American Water Works Association and Water Pollution Control Federation). 1985. Standard Methods for the Examination of Water and Wastewater. 16th edition, 1268 pp, 1985.

Department of Health. State Board of Health Drinking Water Regulations, revised September 1989. 65 pp, 1989.

Ness, A. O. Soil Survey of Thurston County, Washington. Soil Survey, U.S. Department of Agriculture, Series 1947, No. 6, 79 pp, 1958.

Hynes, H.B.N. The Ecology of Running Waters. The University of Toronto Press, 555 pp, 1972.

Pickett, P. Personal Communication. September 1989.

Sinclair, K. and S. Hirschey, 1989. Written Communication. Well information and locations for the Geohydrologic Investigation of the Grand Mound/Rochester Aquifer

Fish Pro, Inc. Draft Engineering Report for Steelhammer Salmon Farm Wastewater Treatment System. 11 pp, 1989.

U.S. EPA. Methods for the Chemical Analysis of Water and Wastes. EPA report 600/4-79-020, Environmental Monitoring and Support Laboratory, Cincinnati, OH, 1983.

Wallace, E.F. and D. Molenaar. Geology and Ground-Water Resources of Thurston, County, Washington. Department of Ecology Water Supply Bulletin No.10, Volumes I and II, 1961.

Appendix A. Rochester Ground Water Quality Assessment- Well Characteristics

Well ID	Owner	State Coordinates X-Coord.	State Coordinates Y-Coord.	Well Elevation LSD (feet)	MP Elevation (feet)	Depth to Water (feet)	Date	Casing Diameter (inches)	Hole Depth (feet)	Screened Interval (LSD,feet)	Well Use	Log
T15/R3W-05A02	Town of Rochester	1354628	553192	150.00	153.60	26.00		10	79	58-73	P	D
T15/R3W-05A03	Town of Rochester	1354588	553282	150.00	153.60	37.77	10/03/89				U	
T15/R3W-05M01	Kenneth Stedham (Fagerness)	1350360	550658	135.00	135.00	31.00	05/31/55	6	55	55	D	D
T15/R3W-05M02	Vince Harrison	1350882	550450	135.00	143.3	32.00	01/31/83	8	60	50-57	D&I	D
T15/R3W-05N01	Ecology, Shallow	1350068	548292	120.00	117.21	6.98	05/10/86	6	67	15-21,40-45,60.5-65	M	D
	Shallow			120.00	117.21							
T15/R3W-06A02	Town of Rochester	1349212	553186	138.00	134.80	36.42	10/03/89	10	70		P	
T15/R3W-06B01	Wilbert Brewer	1348430	553382	135.00	136.89	34.00	06/23/80	6	66	66	D	D
				135.00	136.89	37.67	10/04/89					
T15/R3W-06B02	Larry and Terese Land (Lines)	1348304	552904	135.00	135.82	31.00	04/22/86					
T15/R3W-06B03	"	1348344	553024	135.00	137.21	37.77	10/04/89	6	62	62	D	D
T16/R3W-06C01	Carl Buckingham (Beckham)	1347238	553310	110.00	110.00	15.00	10/24/75	6	42	42	D	D
T15/R3W-06D02	Vernal Page	1345070	552418	110.00	118.30	21.15	10/03/89	8	76		D&I	
T15/R3W-06F01	Kenneth and Kathy Slape	1347142	552072	110.00	115.29	17.24	10/03/89		50		D	
T15/R3W-06G01	George Steelhammer	1348338	551510	110.00	110.00	7.00	05/26/64	10	42	22-27,34.5-39.5	I	D
T15/R3W-06G02	George Steelhammer	1348462	551054	110.00	113.54	8.00	10/25/79	16	62			D
					113.54	11.40	11/16/77					
					113.54	23.51	10/02/79					
T15/R3W-06G03	George Steelhammer	1348740	550922		130.84	24.00	10/31/75	12	75	55-74	I	D
					130.84	32.73	10/02/89					
T15/R3W-06G04	George Steelhammer	1348682	551206		112.73	21.21	10/02/89				I	
T15/R3W-06G05	George Steelhammer	1348818	551092		135.00				12		I	
T15/R3W-06H02	H.T. Voelkel (Arnold)	1349386	551538		135.00	28.00	02/06/74	6	70	70	D&I	D
T15/R3W-06H03	H.T. Voelkel (Arnold)	1349316	551612		137.72	28.00	02/06/74	5	48	48	D&I	D
					137.72	38.96	10/02/89					
T15/R3W-06H04	Tanglewood Mobile Home Park	1349126	552050		137.21	38.53	10/02/89	8	P			
T15/R3W-06K04	Galloway	1348402	549742		119.88	19.18	09/27/89					
T15/R3W-06L01	Jerry and Donna Hall (Baybarz)	1347270	549594		120.99							

Appendix A. (continued)

Well ID	Owner	State Coordinates X-Coord.	State Coordinates Y-Coord.	Well Elevation LSD (feet)	MP Elevation (feet)	Depth to Water (feet)	Date	Casing Diameter (inches)	Hole Depth (feet)	Screened Interval (LSD,feet)	Well Use	Log
T15/R4W-01A02	Marvin Isaacson (Gary)	1344214	553394		115.88	20.00	10/13/77	6	38	38	D	D
					115.88	19.71	10/03/89					
T15/R4W-01D01	Ecology, Shallow	1340902	553612	109.00	110.43			6	136	25-30,60-65,99-104	M	D
					110.43	17.44	10/05/89					
T15/R4W-01H01	Dean Bartleson(Lennart Lund)	1344474	551378		112.32	12.00	08/02/62	6	40			
T16/R3W-31M01	Cal Bartholomew	1345978	555634		120.42	20.00	12/23/81	6	70	70	D	D
					120.42	23.05	10/04/89					
T16/R3W-31N01	Evold Carlson	1345068	554506		114.34	17.00	09/05/84	6	34	34	D	D
					114.34	17.15	10/03/89					
T16/R3W-31P01	McCabe (Riley Bigler)	1347518	553730		114.35	12.40	07/14/50	8	40	35-39		D
					114.35	15.74	10/04/89					
T16/RSW-31P02	Dan and Lola Erhardt	1346660	553940		114.13	16.00	10/03/89	6	42		D	
T16/R3W-31P03	R. J. Moore	1347050	553886		114.19	10.00	05/07/76	6	40	39	D	D
					114.19	16.15	10/04/89					
T16/R3W-31Q03	Neale Rigg	1348314	553794		137.53	38.08	10/04/89	6	55		D	
T16/R3W-31Q04	Carol Moore	1348658	554624		137.93	39.08	10/04/89	6				
T16/R3W-32E01	Blake (Nichols)	1350516	557516	149.00	144.37	45.21	08/30/89	12	93			D
T16/R3W-32G03	Town of Rochester (Lowell Deguise,Gene Weaver Realty)	1353084	556352		147.19	45.74	10/03/89	8	73		P	
T16/R3W-32M02	Schaves (Garcia)	1350930	555372	140.00	141.60	37.00	01/29/79	6	60	60	D	D
						41.83	10/02/89					
T16/R4W-36G02	Mel Youckton	1343026	557024	100.00	105.62	20.00	09/15/86	6	50	49	D	D
						10.83	10/05/89					
SS #1	188th St,Top of Middle Culvert	1348506	550878		115.10	2.94	10/02/89					
SS #2	Highway 12 Bridge, N Side	1347764	553806		121.20	11.00	10/03/89					
SS #3	Forstom Rd Culvert, East Side	1344966	554756		106.46	1.42	10/03/89					

Well Use Designations:
- D = Domestic
- P = Public
- M = Monitoring
- I = Irrigation

LSD = Land Surface Datum

Log Designations:
- D = Driller's log