WATER QUALITY MONITORING of the NISHNABOTNA RIVER ALLUVIAL SYSTEM

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ABSTRACT

Water quality, with particular attention to nitrate and pesticides, was monitored in the Nishnabotna alluvial aquifer during 1987. With respect to major ions, water quality is good except for iron, which tends to be high. Average regional nitrate concentration was 13.2 mg/l NO_3 (2.9 mg/l NO_3-N) for previously collected data and 10.7 mg/l NO_3 (2.4 mg/l NO_3-N) for data collected during this study. This is lower than has been observed in most other alluvial aquifers in the state. Higher average concentrations of nitrate occur in wells located near the valley edge. These wells may be intercepting shallow groundwater flow from the uplands which may have a higher concentration of nitrate. Wells located where the valley is narrow and the aquifer thins also have higher concentrations of nitrate. Vertical stratification of nitrate was not observed in the Nishnabotna alluvial aquifer. Rainfall events did not appear to correlate with increases in nitrate concentration, which may be related to the thick cover of fine-grained alluvium. Nitrate concentrations in surface water were always higher than in groundwater and have increased four-fold over the last ten years.

Pesticides were found at two of six municipal wells during this study. No pesticides were detected in any of the monitoring wells. Examination of all available pesticide data collected between 1985 and 1987 shows pesticide detections at seven of sixteen towns (13 of 60 samples). Most of the concentrations detected are low; alachlor (Lasso) has exceeded the lower limit of the proposed health standard. Atrazine was the most frequently detected compound in groundwater. Pesticide occurence did not correlate with nitrate concentration.

Pesticides were detected in all surface water samples and at higher concentrations than in groundwater. Surface water concentrations of both alachlor and atrazine exceeded the proposed standards. Atrazine and cyanazine (Bladex) were detected most frequently in surface water. Metribuzin (Sencor) was detected only in surface water.

INTRODUCTION

In 1985, the U.S. Geological Survey (USGS) and the Geological Survey Bureau (GSB) of the Iowa Department of Natural Resources undertook a cooperative project to determine the availability and quality of groundwater in nine southwestern Iowa counties: Adair, Adams, Cass, Fremont, Mills, Montgomery, Page, Pottawattamie, and Taylor. Except for localized areas, southwest Iowa is underlain by Pennsylvanian rocks which do not produce good quality water. Therefore, shallow groundwater sources, particularly alluvial aquifers, are an important source of water in southwest Iowa. The Nishnabotna River is the major alluvial system in the western part of this nine county region. Several sets of nested wells (different depth wells at the same site) were installed along the Nishnabotna River alluvial system as part of the cooperative project.

The Geological Survey Bureau, which prior to state government reorganization was the Iowa Geological Survey, has been engaged in studying alluvial aquifers with regard to water availability and quality since 1981. Resulting research in other parts of the State have shown that these shallow aquifers are highly susceptible to contamination and that significant temporal variability in nitrate and pesticide concentrations can occur in alluvial systems (Thompson, 1986, 1987, in preparation). The southwest Iowa Cooperative Project called for a one-time sampling of these wells for minerals, metals, radionuclides, and pesticides. In order to more accurately assess water quality in southwest Iowa, the GSB, in cooperation with the Environmental Protection Division of the Department of Natural Resources, initiated a monitoring project on the Nishnabotna River alluvial system specifically looking at the distribution of nitrate and pesticides.

The occurrence of agricultural chemicals in Iowa's groundwater, even in low concentrations, is of concern because of the potential hazard to health through long-term exposure. High nitrate concentrations have been shown to cause methemoglobinemia, a potentially acute infant disease, as well as being linked to higher incidences of cardiovascular disease, birth defects, and several forms of cancer. There are currently many more questions than answers about the health effects of pesticides or the implication of the coexistence of nitrate, pesticides, and other chemicals. Some studies suggest there is a health risk, but more data are needed to adequately define impacts on human health.

Project Objectives

The objectives of the study were to evaluate the water quality in the Nishnabotna River alluvial aquifer, particularly with regard to nitrate and pesticide concentrations. Specific objectives were to 1) determine whether the aquifer is stratified (has vertical variations in concentration) with respect to nitrate and pesticide concentrations; 2) examine any change in the concentrations with time; 3) compare river water quality to that in the aquifer in an attempt to determine whether actively used wells located near a river are being recharged from the river; and 4) compare water quality between pumping and non-pumping wells.

Study Methods

The Geological Survey Bureau began the monitoring project in 1987. Available water-quality and well-information data were assembled from files maintained by the Iowa Department of Natural Resources. Well information and, where available, geologic logs for the monitoring network are given in Appendix I. Twenty-eight wells (16 municipal wells and six sites with two monitoring wells at each site) and four surface-water sites comprised the monitoring network (Fig. 1). The municipal wells were sampled once a month for nitrate as NO_3 from March through December. The monitoring wells were sampled for nitrate five times between April and August. In addition, pesticide samples were collected at eight of the municipal wells and at all twelve of the monitoring wells during May, June, and July. Samples were analyzed for nineteen pesticides--ten common ag-herbicides and nine insecticides (Table 1). In addition, surface-water sites were monitored for pesticides in June and July and for nitrate in June, July, August, and December.

All six GSB monitoring sites are nested pairs of wells. These are separate wells finished at different depths within the aquifer and installed in the same drill hole. This allows the separate sampling of upper and lower parts of the aquifer which permits an evaluation of potential water-quality stratification. In two locations, a GSB monitoring well was located within two miles of a municipal well to determine if there are significant differences between pumping municipal wells and non-pumping monitoring wells. Two pairs of active municipal wells were also chosen, one close to the river and the other at some distance from the river, to assess the effect of induced river recharge on water quality.

Table 2 indicates the analytical methods and quality control/quality assurance procedures used in this study. All of the samples were analyzed by the University of Iowa Hygienic Laboratory (UHL).

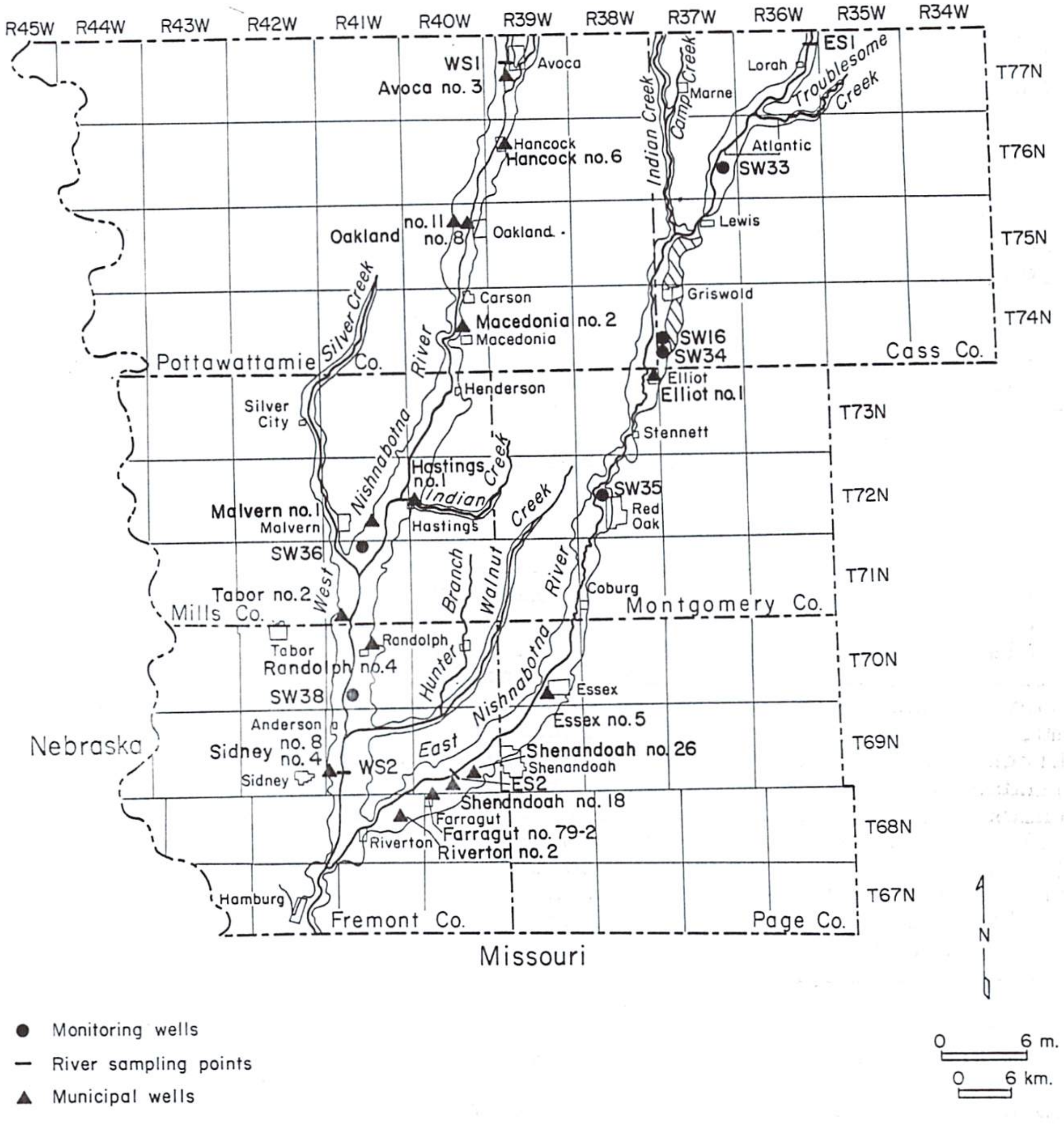

Figure 1. Location of sampling sites - Nishnabotna River alluvial project. All monitoring wells are nested: two at each site.

Table 1. Pesticides monitored.

Herbicides		Insecticides	
common name (active ingredient)	trade name	common name (active ingredient)	trade name
atrazine	(many)	fonofos	Dyfonate
cyanazine	Bladex	diazinon	(many)
metolachlor	Dual	terbufos	Counter
alachlor	Lasso	chlorpyrifos	Lorsban
metribuzin	Sencor	ethoprop	Mocap
pendimethalin	Prowl	dimethoate	(many)
trifluralin	Treflan	phorate	Thimet
butylate	Sutan	malathion	(many)
propachlor	Ramrod	parathion	(many)
sulprofos	Bolstar		

Physiographic and Geologic Setting

The Nishnabotna River is located in southwest Iowa and flows across the Southern Iowa Drift Plain (Prior, 1976). The Southern Iowa Drift Plain is a landscape of steeply rolling hills and incised channels which has evolved since the end of the Pre-Illinoian glaciations. Extensive natural erosion has removed many of the original glacial landforms and left a characteristic, multi-level, stepped erosion landscape (Ruhe, 1969; Bettis and Littke, 1987). Loess, a wind-deposited silt, covers most of the landscape and is thickest near the Missouri River valley. A thick sequence of glacial drift, composed in part of several tills, lies below the loess. Grayish and reddish buried soils (paleosols) are often developed in the top of the glacial tills in the upper levels of the landscape. Upland soils are developed in loess and are silty clay loam or silt loam in texture with moderate hydraulic conductivity. Bedrock throughout most of the region is Pennsylvanian limestones, shales, siltstones, and sandstones. Bedrock surface relief is considerable and there are several well-defined buried channels. Bedrock in portions of Cass and Montgomery counties consists of Cretaceous sandstones and shales. Isolated outliers of Cretaceous rocks are also found, often in an upland position where they have not been removed by erosion.

The study area is the alluvial plain of the river valley. The valley bottom is the nearly flat surface adjacent to the river and is characterized by low relief and poor drainage. The alluvial plain includes the valley bottom and the associated

Table 2. Analytical methods and quality assurance/quality control procedures (from UHL, written communication).

	Nitrate - Nitrite (as NO_3)	Organophosphate Insecticides	Common Ag Herbicides
Sample Matrix	Water	Water	Water
Analytical Method	EPA Method 353.2	EPA Method 8140	EPA Method 619
Sample Preservation	Cool, 4°C	Cool, 4°C	Cool, 4°C
Maximum Holding Time	48 hours	7 days, 40 days after extraction	7 days, 40 days after extraction
Estimated Detection Limit	1 mg/l	0.1 ug/l	0.1 ug/l
Practical Quantitation Limit	1 mg/l	0.1 ug/l	0.1 ug/l
Estimated Accuracy[1]	94% (9%)	104%	114%
Accuracy Protocol	sample spike	spike[2]	spike[2]
Estimated Precision	0.9 (0.9) mg/l[3]	56%[4]	46%[4]
Precision Protocol	replicate	spike[2]	spike[2]

[1] mean percent recovery (1 s.d.)
[2] mean difference (1 s.d.)
[3] percent recovery (s.d.)
[4] in-house (UHL) spike of natural groundwater

terraces. Alluvial terraces along the valley margin are often loess-covered and are between 5 and 25 feet above the valley floor. Much of the alluvial plain is overlain by a thick cover of fine-grained alluvial deposits, up to 40 feet thick. Because of this thick cover, few exposures of alluvial sand-and-gravel deposits occur in the basin. In some locations, the river may cut into the sand and gravel; in most locations however, the bottom of the river remains within the fine-grained alluvial deposits. Surface soils in the valley are developed in silty alluvium and are silt loam to silty clay loam in texture with low to moderate hydraulic conductivity.

The area drained by the Nishnabotna River is 2,819 square miles. At the confluence of the East and West Nishnabotna Rivers, the East Nishnabotna River has a drainage area of 1,148 square miles and the West Nishnabotna River has a drainage area of 1,649 square miles.

Hydrogeologic Setting

In alluvial aquifers like the Nishnabotna River, recharge relationships are complex. Recharge to an alluvial system can occur from infiltration of precipitation, from bank storage of river water, and from seepage from both other aquifers and from the fine-grained glacial materials. Probably a large part of the recharge to alluvial aquifers occurs by infiltration of precipitation through the soil. This is often reflected by the water levels which change throughout the year and are usually highest in late spring and fall which are periods of high rainfall. Recharge to an alluvial system can also occur from seepage from the associated stream during periods of high streamflow (floods). This temporary storage of water in the aquifer is called bank storage and depends on the hydraulic conductivity of the stream/aquifer interface. Recharge and discharge relations may be further complicated by the presence of other aquifers which underlie or are adjacent to the alluvium. In addition, slow recharge to the aquifer through the fine-grained glacial materials may be occurring, representing a significant amount especially in deeper parts of the aquifer. Recharge to the aquifer may also occur from water movement along the loess/till or loess/paleosol interface. Water will infiltrate the loess until it reaches a less permeable material such as till or paleosol. Since vertical permeability is decreased, the water will flow laterally along this surface to a point of discharge. Many of the large-diameter seepage wells in southwest Iowa tap this interface.

There are additional factors which may influence water quality and water movement. The thick fine-grained alluvium capping the alluvial aquifer may prevent rapid infiltration. Organic matter content in fine-grained alluvium also tends to be higher, which may promote degradation or retardation of some chemicals. Where the water table is within these fine-grained deposits a zone of chemical reduction may form and, if sufficient organic matter is present, denitrification, the transformation of nitrate to nitrogen gas, may occur (Thompson, 1986).

WATER QUALITY OF THE NISHNABOTNA RIVER ALLUVIAL AQUIFER

Different data sets were used to evaluate water quality in the Nishnabotna River alluvial aquifer. Previously collected water-quality data were assembled for both major ions and pesticides. Data collected as part of the Southwest Iowa Cooperative Project are also presented here, as well as the monitoring done specifically for this project.

Table 3 lists the National Drinking Water Standards and the significance of each parameter. Drinking water standards have been adopted by the U.S. Environmental Protection Agency as part of the Safe Drinking Water Act (PL 93-523). Primary standards are maximum contaminant levels (MCLs) which are the maximum permissable level of a contaminant in a public water supply. Secondary standards apply to substances which primarily affect aesthetic qualities related to public acceptance of drinking water. In addition to aesthetic degradation, health implications may also exist at considerably higher concentrations for these constituents.

Much of the current concern in Iowa with regard to water quality in alluvial aquifers has focused on agricultural contaminants--nitrate and pesticides. Previous studies in Iowa (McDonald and Splinter, 1982; Hallberg et al., 1984) have shown that regional increases in nitrate concentrations in groundwater and surface water have occurred in direct relation to the increased use of nitrogen fertilizers. It has been well documented that shallow wells (less than 100 feet deep) are especially susceptible to contamination (Hallberg and Hoyer, 1982). Alluvial wells along the Nishnabotna River are generally completed at depths of less than 50 feet. Additionally, alluvial valleys in Iowa are usually intensively farmed, primarily with row crops.

Major Ions

Water-quality data for the major ions were obtained from the University of Iowa Hygienic Laboratory and the Municipal Water-Supply Inventory (MWSI) files which are maintained at the Geological Survey Bureau. Table 4 summarizes untreated groundwater quality for those municipalities in the study area which obtain their water from the alluvium. The water is of high quality with respect to major ion concentration and can be classified as a calcium-magnesium-bicarbonate water. Total dissolved solids concentrations average 450 mg/l, and the water is hard. Iron concentrations can be high and the average

Table 3. Drinking water standards and significance of chemical constituents.

CONSTITUENTS	PRIMARY STANDARDS MCL (All values in mg/l)	SECONDARY STANDARDS	Description/Significance
Dissolved solids		500	This refers to all material that is in solution. It affects the chemical and physical properties of water for many industrial uses. High concentrations will have a laxative effect and may cause an objectionable taste.
Hardness (as $CaCO_3$)			This affects the lathering ability of soap. Primarily caused by calcium and magnesium. Water is generally classified as: soft (0-100 mg/l); moderate (100-200 mg/l); and hard (>200 mg/l).
Specific conductance			A measure of the ability of water to conduct electric current.
Alkalinity			Defined as the capacity of a solution to neutralize an acid.
Iron		0.3	This is objectionable as it may impart an unpleasant taste and may cause discoloration of laundry and porcelain.
Manganese (Mn)		0.05	Objectionable for the same reason as iron.
Potassium (K) and Sodium (Na)			When combined with chloride, imparts a salty or brackish taste. In the presence of suspended matter, causes foaming in boilers. Important ingredients in human cell metabolism. Low sodium diets are prescribed in the treatment of certain types of heart disease and high blood pressure.
Calcium (Ca) and Magnesium (Mg)			These cause water hardness and reduce the lathering ability of soap. They react with bicarbonate and sulfate to form scale in pipes.
Sulfate (SO_4)		250	Commonly has a laxative effect and imparts a bitter taste when concentrations exceed 500 mg/l, particularly when combined with magnesium or sodium. The effect is less when combined with calcium. Persons may become acclimatized to the water, but concentrations above 750 mg/l generally affect everyone. Sulfate combined with calcium causes scale in boilers and water heaters.
Phosphorus (PO_4)			This has been linked to increased eutrophication in lakes and streams. Humans utilize phosphorus in small amounts for bone growth and enzymatic processes.
Chloride (Cl)		250	Imparts a salty taste, especially when combined with sodium and potassium.
Nitrate-N (Nitrate - NO_3)	10 (45)		Concentrations above the recommended limits may cause cyanosis or methemoglobinemia (blue baby syndrome) when used under one year of age. This disease reduces the ability of the blood to absorb oxygen and may be fatal unless properly treated.

Table 4. Range and average concentration for selected major ion constituents in municipal alluvial wells in the Nishnabotna River basin.

All analyses in mg/l

Municipality		Dissolved Solids	Fe	Na	Ca	Mg	NO_3	Cl	SO_4	HCO_3
Avoca	R	443-809	1.4-6.2	11-27	104-164	23-46	<.1-4.5	9.5-52	99-280	292-398
	A	647	3.0	19	139	35	1.6	33	194	349
Hancock	R	496-681	<.02-2.7	12.2-25	109-150	30-52	6.0-47	15-50	85-150	339-400
	A	570	0.44	17	124	37	19.1	34	113	370
Oakland	R	302-480	<.05-2.6	7.4-20.5	69-115	19-30	<.1-3.1	2-13	25-114	285-386
	A	394	1.11	10	91	25	0.8	8	67	328
Carson	R	316-417	0.14-2.0	7.8-10	70-100	22-29	0.2-13	1-14	36-61	300-366
	A	367	0.64	9	87	26	4.6	5	49	340
Macedonia	R	397-709	<.02-0.07	8.7-17	89-160	26-46	0.9-13	<0.5-12	77-230	300-450
	A	516	0.03	11	116	34	6.5	7	144	335
Hendersen	R	395-506	0.04-0.06	10-14	79-100	24-33	6.7-46	8-31	27-68	288-400
	A	440	0.05	12	87	27	30	17	44	327
Hastings	R	388-408	<.02-0.6	10.6-22	77-85	21-28	5.6-26	9-24	54-76	242-280
	A	400	0.2	15	82	25	14	18	67	272
Malvern	R	456-633	<.01-6.7	8-54	75-144	22-31	<.1-14	8-68	57-160	266-466
(Silver Creek)	A	523	2.5	14	113	30	1.9	20	98	387
Malvern	R	361-412	<.01-0.48	11-12	87-100	27-30	0.3-27	9-15	29-70	347-360
(Nishnabotna)	A	385	0.19	12	91	29	12	11	45	352
Silver City	R	491-694	3.5-6.5	10.5-20	99-153	29-44	0.3-0.9	61-92	54-150	303-381
	A	621	4.7	16	135	38	0.6	82	111	348
Tabor	R	315-610	0.02-0.8	8-17.1	67-144	20-50	<.1-16	2-129	12-43	300-366
	A	363	0.26	12	85	26	4.0	24	27	319
Randolph	R	440-514	0.34-2.0	12-15	85-99	35-39	0.8-17	18-32	85-120	327-342
	A	489	1.0	13	94	37	5.8	26	101	335
Sidney	R	333-360	<.01-1.2	10-14	76-84	17-24	2.2-16	3-7.5	9.5-30	300-356
	A	349	.12	12	79	22	8.8	5.6	21	333

R range of concentrations
A average (mean) concentration

Table 4. continued

Municipality		Dissolved Solids	Fe	Na	Ca	Mg	NO_3	Cl	SO_4	HCO_3
Imogene	R	260-271	6.1-6.5	10-11	52-54					248-249
	A	266	6.3	11	53	13	<0.1 2	12		249
Riverton	R	362-387	0.09-1.4	14-19	79-87	23-29	<.1-9.1	1-4	21-36	390-426
	A	385	.77	17	84	26	2.2	3	27	403
Farragut	R	339-492	0.04-2.6	18-21	65-98	22-31	0.7-14	10-31	64-98	221-331
	A	410	.70	19	83	25	5.5	19	79	291
Shenandoah	R	214-800	<.02-8.8	7-29	50-160	13-46	<.1-8.3	3-73	52-275	139-359
	A	500	2.68	16	100	29	1.1	22	151	262
Essex	R	221-377	<0.2-.89	8-19	46-90	9-27	0.8-78	2-22	22-57	142-304
	A	300	.11	11	62	18	30	9	37	212
Elliott	R	193-210	<0.2-.38	6-8	38-43	9-13	1-19	3-7	5-20	145-178
	A	203	.09	7	42	12	15	5	12	164
Marne	R	363-963	<.02-.52	10-26	63-185	27-72	24-97	22-100	78-210	190-461
	A	692	.16	15	128	51	51	65	160	287

R range of concentrations
A average (mean) concentration

concentration (1.20 mg/l) is greater than the secondary standard for drinking water (0.3 mg/l). Sulfate concentrations are low, averaging less than 100 mg/l.

Nitrate analyses from both untreated and treated municipal water show a wide range of values. The drinking water standard listed in Table 3 is 10 mg/l which is for nitrate as nitrogen (NO_3-N). This corresponds to a standard of 45 mg/l for nitrate (NO_3). All of the towns in the Nishnabotna River basin, except for Marne, have average nitrate concentrations below the MCL. The average regional nitrate concentration for these towns is 13.2 mg/l NO_3 (2.9 mg/l NO_3-N). Twelve of the towns are below this average, seven are above. Towns with higher nitrate concentrations are located in areas where the valley is narrow or where the wells are near the valley edge.

River water samples were collected for nitrate-nitrogen in January and February of 1972 and 1977, January of 1975, and September of 1974 by staff of UHL (UHL, 1972, 1975, 1977). These samples were collected from tweleve sites on the West Nishnabotna River, four sites on the East Nishnabotna River, and two sites on Silver Creek. Sites were distributed along the entire river length. Table 5 shows the average (mean) and range for the measured parameters. Some of the measurements on the West Nishnabotna River, especially for organic nitrogen, ammonia nitrogen, chloride, and conductance, are higher than would be expected for natural stream water-quality measurements. These higher measurements were related to point sources which were discharging along the river at the time of sampling. No significant differences were seen between the East and West Nishnabotna Rivers with regard to nitrate-nitrogen. Silver Creek, a main tributary of the West Nishnabotna River, does have higher nitrate concentrations than either the West or East Nishnabotna River. This perhaps indicates that tributary streams may be important in delivering high nitrate loads to the main rivers in this area, but further data are necessary to investigate this hypothesis.

Nitrate-Monitoring Results

The results of the nitrate-monitoring during this study are shown in Table 6. The average (mean) nitrate concentration, including both the municipal and monitoring wells, was 10.7 mg/l NO_3 (2.4 mg/l NO_3-N). This is lower than might have been expected in view of the predicted sensitivity of the alluvial system and the intensive agriculture in the alluvial plain. It is lower than concentrations observed in the alluvial aquifers of the Rock and OcheyedanLittle Sioux Rivers in northwest Iowa (Thompson, 1986, 1987). It is similar, however, to that observed on the West Fork Des Moines River alluvial aquifer where denitrification has been postulated to reduce nitrate concentrations (Thompson, in preparation). In the Nishnabotna River alluvial aquifer, water infiltrating through the fine-grained alluvium into the sand and gravel may become lower in nitrate because of denitrification in the fine-grained alluvium.

Denitrification has been postulated to occur in other alluvial aquifers in the State (Thompson, 1984, 1986; Wehmeyer, in preparation). Denitrification can occur in oxygen-deficient, organic-rich environments such as are present in water-saturated soils and/or silts. Water levels measured during this study (Appendix II) show that the water table is often within the fine-grained alluvium described in Appendix I, which can produce an oxygen-deficient zone. Sufficient organic material may be present in this zone to allow denitrification to occur. If denitrification occurs, water infiltrating to the sands and gravels may be lower in nitrate.

Table 5. Range and average concentration for selected parameters from surface streams in the Nishnabotna River basin (UHL 1972, 1975, 1977).

All measurement in mg/l except as noted

		West Nishnabotna	East Nishnabotna	Silver Creek
Nitrate-N	R	0.4 - 2.6	1.0 - 2.7	2.4 - 3.0
	A	1.5	1.7	2.7
Nitrite-N	R	0.017 - 0.110	0.014 - 0.039	0.015 - 0.058
	A	0.039	0.030	0.031
Organic-N	R	0.33 - 6.9	0.37 - 0.71	0.41 - 2.9
	A	1.4	0.46	1.16
Ammonia-N	R	<0.01 - 27.0	<0.01 - 0.40	<0.01 - 0.47
	A	5.0	0.19	0.26
Alkalinity	R	156 - 441	193 - 222	282 - 318
	A	293	200	298
Phosphate	R	0.1 - 1.1	0.14 - 0.27	0.10 - 0.29
	A	0.37	0.22	0.16
Chloride	R	9 - 280	8 - 16	7 - 39
	A	69	12	16
Hardness	R	276 - 352	238 - 296	316 - 328
	A	322	254	322
Turbidity[1]	R	2.3 - 27	11 - 17	2 - 21
	A	10.9	9	13
Conductance[2]	R	560 - 1700	480 - 600	550 - 680
	A	883	520	633

[1] measured in turbidity units
[2] measured in micromhos

R range of concentrations
A average (mean) concentration

Table 6. Nitrate monitoring results.

(All analyses in mg/l NO_3)

Location	March 1987	April 1987	May 1987	June 1987	July 1987	August 1987	Sept 1987	Oct 1987	Nov 1987	Dec 1987	Average NO3
Municipal Wells - West Fork Nishnabotna River											
Avoca #3	4	4	4	5	2	2	2	4	<1	<1	2.8
Hancock #6	8	7	9	9	9	10	10	9	9	8	8.8
Oakland #8	<1	1	2	3		3	2	3	2	<1	1.9
Oakland #11	2	5	3	4		4	23	5	4	4	6.0
Macedonia #2	13	12	14	16	14	15	17	12	9	9	13.1
Henderson #2				19	21						20.0
Hastings #1	30	30	36	37	27	26		21	22	22	27.9
Malvern #11	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1
Tabor #2	<1	<1	2	2	4	3	2	2	3	2	2.1
Randolph #4	2	20	4	6	14	6	5	5	25	4	9.1
Sidney #8		<1	2		<1		3	<1	<1	<1	<1
Sidney #4	15										15.0
Riverton #2	<1	<1	<1	<1	1	3		2	<1	<1	1.0
Farragut 79-2	10	16	7	8	9	11	16	8	7	7	9.9
Shenandoah #18		<1	<1	2	2	2	2	<1	<1	<1	1.2
Shenandoah #26	42	38	40	38	40	39	39	42	47	44	40.9
Essex #5	5	4	5	5	6	5	6	6	5	5	5.2
Elliott #1	22	21	27	21	22	23	21	21	22	22	22.2
Monitoring Wells											
SW36U		<1/<1	<1	<1/<1	1	2					<1
SW36L		<1/<1	<1	<1	1	<1					<1
SW38U		<1/<1	<1		1	3					1.0
SW38L		<1/<1	<1	<1	1	1					<1
SW33U		37/36	49	7	20/22	32					29.1
SW33L		<1/<1	10	14	80	139					48.8
SW16U		<1/<1	<1	1	2	6					2.0
SW16L		4/4	6	8	7/7	2					5.4
SW34U		<1/<1	<1	<1	1	2					<1
SW34L		<1/<1	<1	1	2	3					1.4
SW35U		26/26	29	46	27/27	24					30.4
SW35L		23/23	23	20	21/22	23					22.1
Stream Station											
ES1					39	36				39	38.0
ES2					28	21				22	23.7
WS1					33	29				33	31.7
WS2					34	30				29	31.0

Two results indicate duplicate sampling

Measured concentrations of nitrate greater than 10 mg/l NO_3 (2.2 mg/l NO_3-N) seem to be restricted to a few areas and correspond well to areas where high nitrate concentrations were previously present as shown in the historical data. On the West Nishnabotna River, elevated concentrations were found at four municipal wells; Macedonia #2, Henderson #2, Sidney #4, and Hastings #1. On the East Nishnabotna River, four locations show elevated nitrate concentrations--two municipal wells (Elliot #1 and Shenandoah #26) and two nested well sets (SW33 and SW35). For some municipal wells, higher than background nitrate concentrations appear to correlate with wells located near the valley wall. Although exact mechanisms have not been studied, the higher nitrate concentration in these wells may result from the interception of shallow upland flow systems. The uplands in this area are covered by a thin layer of loess over a paleosol or till. Loess has a higher hydraulic conductivity, or ability to transmit water, than does the underlying till or paleosol. Water will infiltrate until it reaches this boundary, whereupon it will flow along the boundary until it reaches a discharge point. Flow is often concentrated along this interface and nitrate concentrations are often high (Freeze and Cherry, 1979; GSB unpublished data). Since the wells are located very near the valley edge, they may be intercepting this flow containing higher nitrate concentrations.

Wells located further from the valley wall may not be as affected by this shallow flow from the uplands. If denitrification does occur and is significant within the fine-grained alluvium, then water infiltrating to the alluvial sand and gravel in the valley could be lower in nitrate. Dilution of the higher nitrate flow from the uplands thus results. At Sidney, well #4 has a higher nitrate concentration than well #8 which is located further out into the valley which tends to support this theory.

There are exceptions to this trend. The wells at Tabor are located on an alluvial fan near the valley edge and yet have low nitrate concentrations. Other wells, located away from the valley wall, have elevated nitrate concentrations such as Shenandoah #26. None of the other wells in the Shenandoah well field show elevated nitrate concentrations and there is no apparent reason for this unless land use or chemical-application patterns are different near this site. Alternatively, well construction could be a problem.

Two of the nested monitoring well sets also show elevated nitrate concentrations and yet are located away from the valley wall. Nitrate concentrations at SW35 are high in both the upper and lower wells. This site is different from others previously discussed in several ways. The valley is narrow at this point and the alluvial deposits are thinner. The overlying fine-grained alluvium is also thinner at this site than at most of the other nested sites and thus these are the two shallowest wells in the study area. These wells may be tapping a shallower flow system than other wells. Also, denitrification may not be as effective here. Similar settings in other alluvial valleys also show higher nitrate concentrations where the alluvium thins (Thompson, in preparation). Nitrate concentrations at SW33 are noticeably different between the upper and lower wells. The aquifer is stratified at this site and consists of a series of sand and gravel units alternating with silts (Appendix I). The upper well is completed in the second sand and gravel layer encountered at the site. The lower well is completed in a sand and gravel layer at the base of the glacial materials. Over the monitoring period there was a steady increase in nitrate concentration in the lower well. Since the exact mechanism of recharge to these lower units is unknown, it is difficult to speculate on a cause for the elevated concentrations of nitrate. The recharge area for these lower aquifers may be widely separated and influenced by different land use and/or chemical application patterns.

Temporal Variability of Nitrate

Nitrate concentrations in alluvial aquifers have been shown to be highly variable over time with increases in nitrate concentrations directly tied to precipitation events (Thompson, 1987, in preparation). Changes in water levels in wells could not be directly correlated with specific precipitation events, however in at least one well water levels did change a maximum of 10.94 feet which does relate to precipitation influences. Nitrate concentrations also could not be directly tied to precipitation events. Nitrate concentrations in the municipal wells were consistent over the monitoring period. Several municipal wells have been on a more frequent nitrate sampling schedule because of State requirements (Oakland, Hendersen, Hastings, Essex, and Marne) and the nitrate concentrations in these wells are also remarkably consistent.

There are few data available to explain the differences between the Nishnabotna alluvial aquifer and other alluvial systems. Since fine-grained alluvial deposits are present over the sand and gravel, the Nishnabotna system may show a delayed response to precipitation events that could not be discerned given the monitoring frequency. Southwest Iowa was subject to unusually heavy rainfall throughout the summer of 1987. While greater recharge may have been expected, the water levels do not appear to correlate with these hydrologic events, except in June. Later summer storms, although larger in magnitude, did not directly affect water levels. Because of previous wet conditions, the soils in the area may have already been saturated and drainage of these high-magnitude rain events may have occurred primarily by overland flow and tile drainage, rather than infiltration and groundwater recharge. River discharge data (USGS, ADAPS data base) show that river levels are extremely responsive to precipitation events, and that overland flow is important in the basin.

Vertical Stratification of Nitrate

Previously studied alluvial systems have shown pronounced vertical stratification, with nitrate decreasing with depth (Thompson, 1986, 1987, in preparation; Hendry et al., 1983). This has been attributed to the flow system within an alluvial aquifer which tends to favor lateral transport over vertical dispersion. Stratification with respect to water quality could have important ramifications for well placement if the stratification is neither disrupted by pumping nor a temporal phenomena.

Six sets of nested wells were installed along the East and West Nishnabotna Rivers. With the available data it is difficult to assess whether the aquifer is stratified. More wells and additional water-quality and water-level measurements would be needed to support any conclusions. However, a few tenative correlations can be made. Table 7 relates well depth, based on screened interval, to nitrate concentration. Nitrate appears to decrease with depth, but this may be misleading because of the limited number of wells. Only one of the individual nests shows a decrease in nitrate concentration with depth. One of the nests was completed in different upper and lower units (SW33), and is not useful in assessing nitrate stratification within the alluvium. In three of the remaining five nests (SW34, SW36, SW38), nitrate is generally less than 1 mg/l NO_3 (0.2 mg/l NO_3-N), and no conclusions with regard to stratification can be drawn. SW16 shows a slight increase between the upper and lower wells. Higher nitrate concentrations in deeper wells have been observed in other alluvial systems (Thompson, 1987, in preparation). In SW35, there is a slight decrease in nitrate concentration with depth. The data are thus equivocal and no conclusions can be drawn as to whether the Nishnabotna alluvial aquifer is

Table 7. Vertical distribution of nitrate in GSB monitoring wells.

Screened Interval (ft)	# of Wells	NO_3 (NO_3-N) mg/l Range	Mean
0-10	--	--	--
10-20	1	24-46 (5.3-10.2)	30.4 (6.8)
20-30	2	<1-23 (<0.2-5.1)	11.5 (2.6)
30-40	4	<1-49 (<0.2-10.9)	8.4 (1.9)
>40	3	<1- 2 (<0.2-0.4)	<1 (<0.2)

stratified with respect to nitrate. Since the water table is often within the fine-grained alluvium, higher concentrations of nitrate might be near the water table within the fine-grained alluvial deposits. However, no wells were installed in the fine-grained alluvium to test this hypothesis.

Pumping Effects on Nitrate Distribution

It has been suggested in other studies of alluvial systems that differences in water quality may exist between non-pumping monitoring wells and active municipal wells (Kelley, 1988; Thompson, in preparation). The limited data collected in the Nishnabotna River basin shows that a slight difference may exist between active and nonactive wells. To determine whether differences did exist, two pairs of monitoring wells were located within two miles of an active municipal system. SW34 was close to Elliott and SW36 was located near Malvern. No nitrate was detected in either the Malvern well or the monitoring well. There were differences noted between the Elliott well and SW34, with nitrate concentrations being higher in the Elliott well. However, as previously discussed, this may be caused by interception of a shallow flow system at Elliott and unrelated to pumping effects.

For the samples collected during this study, average nitrate concentrations are 10.1 mg/l NO_3 (2.2 mg/l NO_3-N) in the municipal wells and 6.2 mg/l NO_3 (1.4 mg/l NO_3-N) in the monitoring wells. This does not include the monitoring wells which were finished in a buried sand and gravel. Table 8 shows a comparison of municipal well and monitoring well samples broken down into four nitrate classes. The percentages of samples in each nitrate class for the two types of wells are similar. For monitoring wells, the samples are somewhat evenly divided between the <1 mg/l NO_3 (<0.2 mg/l NO_3-N) category and the 1-21 mg/l NO_3 (0.2-4.7 mg/l NO_3-N) category. Most of the municipal-well samples fall in the range 1-21 mg/l NO_3 (0.2-4.7 mg/l NO_3-N) , and the percentage of wells in this category is about one-and-a-half times greater for the municipal wells than the monitoring wells. Fewer municipal wells are in the range <1 mg/l NO_3 (<0.2 mg/l NO_3-N) . Thus, there may be a slight difference between municipal and monitoring wells. This could be caused by several factors. Although stratification in the system is unproven, higher nitrate concentrations may be present within the upper, fine-grained alluvial deposits. Pumping may integrate water from the entire alluvial sequence causing nitrate levels to be slightly higher. Alternately, local sources within a community may be affecting municipal wells.

Table 8. Comparison of nitrate concentrations in municipal and monitoring wells.

NO_3 (NO_3-N) mg/l	Number of Samples Municipal	 Monitoring	Total
<1 (<0.2)	31 (20%)	19 (39%)	50 (25%)
<1-21 (<0.2-4.7)	97 (63%)	21 (44%)	118 (58%)
22-45 (4.9-10)	25 (16%)	8 (16%)	33 (16%)
>45 (>10)	1 (1%)	1 (1%)	2 (1%

Surface Water

In alluvial systems, groundwater and surface water are closely interconnected. During periods of low rainfall, streamflow is maintained by groundwater flow (baseflow). Even during rainfall periods, a certain portion of streamflow is from groundwater. Thus, water quality in the stream can be indicative of water quality in groundwater.

Surface water at four different sites (Fig. 1) was sampled three times. Nitrate concentrations are higher than those observed in alluvial groundwater during this study, and have apparently increased since the 1970s. The two sampling stations on the West Nishnabotna River (WS1, WS2) showed similar nitrate concentrations and averaged 31.3 mg/l NO_3 (7.0 mg/l NO_3-N) (Table 6). Samples from the East Nishnabotna River (ES1, ES2) averaged 30.8 mg/l NO_3 (6.8 mg/l NO_3-N), but showed a consistent downstream decrease in nitrate concentration. The upstream station averaged 38 mg/l NO_3 (8.4 mg/l NO_3-N) while the downstream station only averaged 23.7 mg/l NO_3 (5.3 mg/l NO_3-N). This trend may be apparent as it is based on only a few samples, but if real, it could be caused by in-stream denitrification which has been cited as an important factor in reducing nitrate loads in streams (Hill, 1983, 1981; Wyer and Hill, 1984). However, if this were true, the decrease might have been expected to be less in the winter due to lessened biological activity. This was not observed in the data collected. Differences in land use in the two river sub-basins could also provide a possible explanation.

Comparing the current data to that previously collected, nitrate concentrations in the Nishnabotna River appear to have increased since the 1970s. Samples collected from 1972-1977 (UHL, 1972, 1975, 1977) had mean nitrate concentrations of 6.7 and 7.7 mg/l NO_3 (1.5 and 1.7 mg/l NO_3-N) for the West and East Nishnabotna Rivers respectively. Mean nitrate concentrations for 1987 show an approximate four-fold increase over a span of about ten years.

Nitrate concentrations are higher than those commonly seen in groundwater in the area. However, river samples integrate a larger area than just that of the alluvial groundwater. Shallow upland groundwater flow systems contribute water with high nitrate concentrations to tributary streams. Data from Silver Creek, a main tributary to the West Nishnabotna River, does show higher nitrate concentrations carried by the tributaries. Interception of infiltrating water with high nitrate concentrations by drainage tiles, with subsequent delivery to the stream system, may also increase nitrate loads in the river.

Effects of River Recharge

River recharge may have a significant effect on water quality in pumping wells, because high pumpage rates in wells located near a river can induce flow from the river into those wells. In other alluvial basins in western Iowa, stream-related effects have been postulated to be a possible cause of water quality degradation (Kelley, 1988). Although it would take many wells to adequately document this phenomena, an attempt was made to analyze whether it could be significant in the Nishnabotna basin. Two sites (Oakland and Shenandoah) were chosen that had a pair of municipal wells located at different distances from the river.

The limited data collected are inadequate to fully ascertain the effects of induced recharge. No trends were seen at either of the sites chosen for analysis. Oakland #8 is located about 2600 feet west of the West Nishnabotna River and showed generally very low nitrate concentrations throughout the monitoring period. Oakland #11 is located about 5200 feet west of the West Nishnabotna River and had a slightly higher average nitrate concentration. However, both wells were within normally observed background concentrations of nitrate. The other study site was at Shenandoah. Shenandoah #18 is about 2100 feet east of the East Nishnabotna River; well #26 is 6200 feet east of the river. The concentration of nitrate was 2 mg/l NO_3 (0.4 mg/l NO_3-N) or lower at well #18, while at well #26 nitrate averaged 41 mg/l NO_3 (9.1 mg/l NO_3-N) Since the nitrate concentration in the two wells was very different and, as explained previously, there was no apparent reason for the high nitrate concentration at well #26, an attempt was made to use pesticides as an indicator of river water recharge. During the sampling period, several pesticides were detected in river samples in the East Nishnabotna River. Samples for pesticide analysis were collected at both Shenandoah wells, but no pesticides were found at either well.

Further studies will be needed in several basins to adequately study the possible effects of induced recharge. However, few municipal wells are located very near the rivers in the Nishnabotna River basin, probably because of the variable discharge which characterize these streams, thus limiting the possible recharge effects.

Pesticide-Monitoring Results

There has been increasing concern over the presence of pesticides in drinking water supplies. The U.S. Environmental Protection Agency is still reviewing many of the compounds that are commonly found. Table 9 lists the health advisories and risk assessment concentrations which have been proposed. Risk assessment concentrations correspond to a one-in-a-million risk for carcinogenic chemicals. The only pesticide that is commonly found that is considered carcinogenic is alachlor (Lasso). The risk assessment shows a range of acceptable concentrations. Iowa is using a risk assessment concentration of 1.5 µg/l (ppb). Other states have suggested a risk assessment concentration of 0.5 µg/l. Health advisories are guides for those dealing with potential contamination; they are not legally enforceable. These are only proposed values and are still under review.

Pesticide data from previous monitoring were compiled from the USGS untreated water sampling program and the IDNR one-time sampling of finished water supplies (IDNR, 1988) (Appendix III). Data were available for 17 wells in 15 towns. For the present study, water samples were collected for pesticide analysis in May, June, and July of 1987 from eight municipal wells and the twelve monitoring wells (Appendix IV). In addition, samples for pesticide analysis were collected at four river sampling locations in June and July, 1987 (Appendix IV).

Overall in groundwater, pesticides were detected infrequently and in low concentrations. Pesticides were found in all surface-water samples collected, and in generally higher concentrations than in groundwater samples. In surface water, alachlor and atrazine have exceeded the recommended standards. Table 10 summarizes detections in municipal wells compiled from both the previously collected data and those collected during this study. The data were collected between 1985 and 1987 at 22 individual wells in 16 towns (60 samples). Most of the sampling was done in the summer months; seven of the samples were collected during winter. The surface-water sampling was all done in June and July of 1987 from four sites.

Examination of previously collected data showed that detections of pesticides occurred at seven wells in six towns (37 samples). Atrazine was detected most frequently with detections ranging from 0.16 µg/l to 0.88 µg/l. Metolachlor was detected twice at concentrations of 0.1 and 0.64 µg/l. Alachlor was the only other compound detected, and occurred at only one site with a concentration of 0.87 µg/l. In the monitoring for this study

Table 9. Tentative standards for pesticides in drinking water.

	Health Advisories (ppb)	Risk Assessment Concentration(ppb)
alachlor		0.15 - 1.5
atrazine	2.5	
cyanazine	9.0	
metolachlor	10.5	
metribuzin	175.0	
simazine	35.0	

Table 10. Summary of pesticide detections - Nishnabotna River alluvial system (1985-1987).

Frequency of Occurrence

Pesticide Detections/# Samples (# Pesticide Detections/# Towns)

	Municipal Wells	Surface Sites
atrazine	8/60 (6/16)	4/8
cyanazine	1/60 (1/16)	4/8
metolachlor	2/60 (2/16)	3/8
alachlor	1/60 (1/16)	0/8
simazine	1/60 (0/16)	3/8

Concentration Range (µg/l)

	Municipal Wells	Surface Sites
atrazine	0.16 - 0.88	0.13 - 4.15
cyanazine	1.7	0.15 - 7.10
metolachlor	0.10 - 0.64	0.84 - 1.20
alachlor	0.87	0.35 - 0.73
simazine	0.98	
metribuzin		0.28 - 0.33

(23 samples), atrazine was detected at two municipal wells (Avoca #3, Oakland #11) with concentrations between 0.16 to 0.39 µg/l. Cyanazine was detected once at Oakland #11 at a concentration of 1.7 µg/l. Simazine was detected once at Avoca #3 at a concentration of 0.98 µg/l. Pesticides were not detected at any of the monitoring wells.

Detections of multiple compounds has often been used as an indicator of local sources of contamination. More than one compound was detected at two municipalities (Avoca and Oakland) during this study. An examination of the individual settings shows that most of the wells are located upgradient of any potential sources of local contamination. The concentrations found are also lower than in situations attributable to point-source contamination.

Pesticide concentrations also vary through time and are usually highest following a rainstorm immediately after application. One municipality (Avoca) had a repeated detection of atrazine during the study, with the concentration decreasing throughout the sampling period. Atrazine had also been detected in previous monitoring of this water supply. Atrazine has been the most common pesticide found in Iowa groundwater, which can be attributable both to its common useage as well as its solubility.

Pesticides were found in all surface-water samples. More compounds and higher concentrations were detected in June than in July. This may relate to increased infiltration and runoff from large rains over the basin in May, as well as with chemical or biological breakdown of these compounds with time. Concentrations also increased noticeably between upstream and downstream stations indicating substantial inputs from within the basin. Atrazine was detected at all surface-water sites in both months, with concentrations ranging from 0.21 to 4.15 µg/l. Cyanazine was also found at all four stations in both months with the exception of the upstream sites on the East Nishnabotna River (ES1) in June. Concentrations ranged from 0.11 to 7.10 µg/l. Three other compounds were detected only in June--metolachlor, alachlor, and metribuzin.

There has been an interest in correlating the occurrence of pesticides with nitrate concentrations. It has been thought that wells with higher concentrations of nitrate would be likely to have detectable pesticides. Table 11 shows nitrate concentration versus pesticide detections for wells with positive pesticide detections in the Nishnabotna River basin and in other southwest Iowa alluvial basins (Hansen et al., in preparation). Most of the pesticide detections are found in wells with low to moderate nitrate concentrations (<25 mg/l NO_3 (<5.6 mg/l NO_3-N)). This data may not be representative because of the small number of wells with high concentrations of nitrate. A tentative conclusion can be reached that nitrate concentration is not a good predictor of pesticide occurrences in southwest Iowa.

Table 11. Nitrate concentration versus distribution of pesticides.

	# Pesticide Detections/ # Samples	
NO_3 (NO_3-N) mg/l	Alluvial Wells in Nishnabotna Basin	Alluvial Wells in Other SW Iowa Alluvial Basins
<1 (<0.2)	1/9	3/9
1-25 (0.2-5.6)	6/23	2/4
25-45 (5.6-10)	1/10	0/1
>45 (>10)	0/1	0/0

SUMMARY

Alluvial aquifers in southwest Iowa are important sources of water for many rural residents, municipalities, rural water systems, and irrigators. The water in the Nishnabotna alluvial aquifer is of good quality with respect to the major ions, and is a calcium-magnesium-carbonate type like many of the waters in Iowa. Iron concentrations are variable and are often above the recommended limit. Since much of the current concern with regard to groundwater contamination focuses on agricultural contaminants, nitrate and pesticide concentrations were extensively monitored. The average regional nitrate concentration from data collected over the last ten years is 13.2 mg/l NO_3 (2.9 mg/l NO_3-N), which is lower than has been seen in most other alluvial aquifers in Iowa. Surface water samples collected in the mid-1970s had average nitrate concentrations below 8 mg/l NO_3 (1.8 mg/l NO_3-N).

In order to assess current nitrate and pesticide concentrations as well as evaluate temporal variability, vertical stratification, pumping effects, and effects of river recharge on groundwater quality, a monitoring project was begun in March, 1987. Sixteen municipal wells were sampled monthly for nitrate through December of 1987. GSB monitoring wells were sampled for nitrate five times between April and August, 1987. Pesticide samples were collected at eight of the municipal wells and all of the monitoring wells during May, June, and July. Surface-water samples for nitrate were collected in June, July, August, and December, and for pesticides in June and July.

In this study, the average nitrate concentration in both the municipal and monitoring wells was 10.7 mg/l NO_3 (2.4 mg/l NO_3-N). The lower concentrations of nitrate may result from denitrification within the overlying fine-grained alluvium. This would have the effect of lowering nitrate concentrations delivered to the underlying sand and gravel. Alternately, higher concentrations of nitrate may move laterally through the fine-grained alluvium into the river. The water table is within this fine-grained material and the few water levels measured in the nested wells indicate that vertical gradients are very low. However, all of the wells are in the sand and gravel; none are within the fine-grained alluvium.

Higher concentrations of nitrate (>10 mg/l NO_3 (>2.2 mg/l NO_3-N)) appear to correlate with well location within the valley. Many of the wells with high average nitrate concentrations are located near the valley edge. It is hypothesized that these wells are intercepting shallow groundwater flow from the uplands. Water flowing along the loess/till or loess/paleosol contact may be higher in nitrate, and the municipal wells along the valley edge may be intercepting this flow. However, not all wells located near the valley edge show elevated concentrations, and there are some wells in other locations which also have higher concentrations. One of the nested well sets is located near the middle of the valley, but occurs where the alluvium is thinner. This well set may be tapping a shallower flow system than other wells within the aquifer and thus intercepting higher nitrate concentrations.

Pronounced temporal variability of nitrate occurs in other alluvial aquifers and could be directly related to recharge events. Although several large rains did occur over the Nishnabotna basin during the monitoring period, no large increases in nitrate concentration were observed in the wells. Water levels also did not appear to respond directly to the increased rainfall. Many of the larger storms may have been dissipated by overland flow and tile drainage.

Vertical stratification of nitrate has also been observed in several other alluvial systems in Iowa. There are slight indications of stratification in the Nishnabotna alluvial system, but lack of data prevents any significant conclusions from being reached. The shallowest wells do show the highest nitrate concentrations; however, no individual well-set shows a vertical trend. If the entire saturated thickness, including the fine-grained alluvium, were examined, a more complete picture might emerge. It may be possible that higher concentrations are often restriced within the fine-grained section of the aquifer.

It has been previously hypothesized that pumping a well might increase the concentration of contaminants. There have been differences noted in the past between active and non-active wells. Only two pairs of monitoring wells were located close enough to active municipal wells to serve as comparisons. Neither set proved useful in distinguishing active from non-active wells based on water quality. Average nitrate concentrations are slightly higher in the municipal wells, but as previously discussed, this may be due to well location within the valley.

Nitrate concentrations were always high in surface water, averaging over 30 mg/l NO_3 (6.7 mg/l NO_3-N). Comparison with previously collected data show that nitrate concentrations have increased four-fold over a span of ten to fifteen years. Both the West and East Nishnabotna Rivers show similar nitrate concentrations, but the East Nishnabotna River displayed a downstream decrease in nitrate concentration. This decrease may be caused by in-stream denitrification, but other factors may also be responsible.

Induced recharge from rivers into wells has been used as a possible explanation of both high nitrate concentrations and the presence of pesticides in some municipal wells. Two sites were used to examine this hypothesis, but the data were inadequate to reach any conclusions.

Pesticide data collected between 1985 and 1987, as well as that collected during this study, were analyzed to determine the frequency of occurrence. Over this period of time, at least one pesticide was detected at seven of sixteen towns (13 of 60 samples). Concentrations in groundwater are low, although alachlor was detected at a concentration within the range of the proposed health standard. Atrazine was the most frequently detected compound in groundwater. Multiple compounds were detected at two municipalities, but the concentrations were less than might be expected from point-source contamination.

Pesticides were detected in all surface water samples and at higher concentrations than in groundwater samples. Both alachlor and atrazine have exceeded the proposed standards in surface water. Atrazine and cyanazine were detected during all sampling periods, while three other compounds were detected only in June. Metribuzin was only found in surface water. Data are limited, but pesticide occurrence was not found to correlate with nitrate concentration.

Overall, water quality is fairly good in the Nishnabotna alluvial aquifer. The possibility of future degradation cannot be ruled out, but long term trends cannot be ascertained. Since alluvial supplies are so important in southwest Iowa, groundwater quality should continue to be monitored.

FURTHER RESEARCH

Further research is needed to better understand the occurrence of agricultural chemicals in groundwater. The results of this preliminary study indicated possible research for the future. A better understanding of the flow system in these southwestern alluvial aquifers is needed. Stratification within the alluvial package could be assessed by the addition of more nested well sites and more wells at each of the sites. Wells in the fine-grained alluvium are necessary both to assess possible chemical degradation as well as to enable determination of vertical flow gradients. Additional wells are also needed to further define the inter-relationships between the alluvium and the surrounding materials. Wells located along the valley edge may further help to clarify the proposed relationship between shallow upland flow and the alluvial aquifer.

More frequent monitoring at groundwater, especially during precipitation events, will further increase our understanding of recharge mechanisms. In addition, more frequent monitoring will allow a better assessment of temporal variability of nitrate and pesticide concentrations in groundwater. The disparity between both nitrate and pesticide concentrations in surface water versus groundwater could be addressed by intensive monitoring of wells, rivers, and tributaries during rainfall events. In this way, it may be possible to define the relative contributions of overland flow relative to groundwater discharge.

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APPENDIX I

Well Information and Geologic Logs - Nishnabotna River Alluvial Project Monitoring Sites

Municipal well information from the Geological Survey Bureau's Municipal Water-Supply Inventory

Avoca #3 location: NE,SW,SE,SW,NE, Sec. 17, T77N, R39W Pottawattamie Co.
elevation: 1225′ depth: 39′6″ casing: 0′- 28′ of 16″
28′- 39′6″ of screen

Hancock #6 location: SW,SW,SW, Sec. 08, T76N, R39W Pottawattamie Co.
elevation: 1107′ depth: 48′

Oakland #8 location: NE,SE,NE,SW, Sec. 11, T75N, R40W Pottawattamie Co.
elevation: 1080′ depth: 30′ casing: 0′- 20′ of 16″
20′- 30′ of 16″ screen

driller's log:
0′- 4′ black topsoil
4′- 14′ brown clay
14′- 17′ fine sand
17′- 24′ coarse to fine sand
24′- 30′ gravel; coarse sand; boulders
30′--- blue clay

Oakland #11 location: NW,NW,NE,NE,SE, Sec. 10, T75N, R40W Pottawattamie Co.
elevation: 1098′ depth: 42′

Macedonia #2 location: SW,SW,SE,NE,NE, Sec. 22, T74N, R40W Pottawattamie Co.
elevation: 1057′ depth: 38′

Henderson #2 location: SE,NE,NE,SW,NE, Sec. 10, T73N, R40W Mills Co.
elevation: 1071′ depth: 66′

Hastings #1 location: SW,SE,NE,SE, Sec. 24, T72N, R41W Mills Co.
elevation: 1003′ depth: 53′ casing: 0′- 48′ of 12″
48′- 53′ of 12″ screen

driller's log:
0′- 19′ mixed cover
19′- 23′ blue clay
23′- 25′ fine to medium sand
25′- 40′ coarse sand & gravel
40′- 53′ fine to medium sand & gravel

Malvern #11 location: SW,SW,SW,SE,SW, Sec. 27, T72N, R41W Mills Co.
elevation: 1012' depth: 56' casing: 0'- 41' of 12"
41'- 56' of screen

test hole log:
W-25363

0'- 10'	brown, silty soil
10'- 20'	yellow, argillaceous silt
20'- 33'	yellow & gray, very argillaceous silt
33'- 40'	colorless, yellow, orange, dark red, dark (heavy), medium to fine & coarse, subrounded to angular sand
40'- 56'	colorless, yellow, orange, dark red, dark (heavy), coarse to fine, subrounded to angular sand; subrounded gravel
56'- 62'	light olive gray, unoxidized, unleached till

Tabor #2 location: NW,NW,NE,NE, Sec. 06, T70N, R41W Fremont Co.
elevation: 984' depth: 62' casing: 0'- 47' of 16"
47'- 62' of 16" screen

driller's log:

0'- 3'	topsoil
3'- 18'	brown clay
18'- 35'	blue clay
35'- 56'	coarse sand; fine sand & gravel
56'- 58'	blue clay & boulders
58'- 62'	blue sand; gravel; & boulders

Randolph #4 location: SE,SW,SW,SE, Sec. 09, T70N, R44W Fremont Co.
elevation: 980' depth: 52' casing: 0'- 32' of 10"
32'- 52' of 10" screen

Sidney #North Springs location: NE,SE,NE,NW,NW, Sec. 31, T69N, R41W Fremont Co.
elevation: 942' depth: 52' casing: 0'- 10' of 156"
Note: an open bottom reservoir is over North Springs.

Sidney #4 location: SW,NW,NE,NW, Sec. 31, T69N, R41W Fremont Co.
elevation: 940' depth: 28'
Note: this well is a 100' long infiltration gallery, which drains into the North Springs open bottom reservoir.

Sidney #8 location: NE,SW,NE,NW, Sec. 31, T69N, R41W Fremont Co.
elevation: 922' depth: 32' casing: 0'- 22' of 8"
22'- 32' of 8" screen

driller's log:

0'- 10'	black soil
10'- 16'	blue clay
16'- 20'	fine & coarse sand
20'- 30'	fine & coarse sand & gravel
30'- 31'	wood

31′- 32′ coarse sand & gravel
32′--- blue glacial clay

Riverton #2 location: NW,NE,SW, Sec. 14, T68N, R41W Fremont Co.
elevation: 933′ depth: 57′ casing: 0′- 47′ of 8"
47′- 57′ of screen

Farragut #79-2 location: NE,NE,NE,SW,NW, Sec. 07, T68N, R40W Fremont Co.
elevation: 953′ depth: 72′ casing: 0′- 42′ of 10"
42′- 72′ of screen

driller′s log:
0′- 3′ soil
3′- 20′ brown clay
20′- 28′ blue clay
28′- 35′ sand
35′- 64′ coarse sand & gravel
64′- 70′ blue shale

Shenandoah #18 location: SW,SE,SE, Sec. 28, T69N, R40W Fremont Co.
elevation: 946′ depth: 36′
Note: this well is used during the summer only.

Shenandoah #26 location: SW,SE,SE,NW, Sec. 26, T69N, R40W Fremont Co.
elevation: 954′ depth: 36′ casing: 0′- 26′ of 18"
26′- 36′ of 18" screen

driller′s log:
0′- 3′ topsoil
3′- 9′ gray clay
9′- 13′ blue clay
13′- 21′ coarse to fine sand
21′- 33′ gravel to coarse sand, buff
33′- 33.5′ blue clay
33.5′- 36′ gravel to coarse sand, blue
36′--- blue shale

Essex #5 location: NW,NW,NE,SE,SE, Sec. 27, T70N, R39W Page Co.
elevation: 988′ depth: 44.5′
test well driller′s log:
0′- 20′ gray clay
20′- 25′ fine coarse sand
25′- 42′ coarse gravel

Elliott #1 location: SE,SW,SE,NW,SE, Sec. 01, T73N, R38W Montgomery Co.
elevation: 1073′ depth: 56′

Geological Survey Bureau's monitoring well information

SW36 W-27836 location: NE,NE,NE,NE, Sec. 4, T71N, R41W Mills Co.
elevation: 997' depth: 69' SW36U casing: 0'-40' of 2"
40'-44' of 2" slotted
SW36L casing: 0'-57' of 2"
57'-62' of 2" screen

log: Quaternary	0'- 3'	Topsoil (driller's log)
	3'- 5'	Clay, yellow-gray, silty (driller's log)
	5'- 8'	Silt, pale yellow, very argillaceous
	8'- 16'	Silt, orange, very argillaceous
	16'- 20'	Silt, orange, very argillaceous, calcareous
	20'- 27'	Silt, very pale yellow, very argillaceous, calcareous
	27'- 29'	Silt, brown-gray, argillaceous
	29'- 30'	Sand, colorless and dark (heavy), coarse to fine; gravel
	30'- 32'	Silt, gray, very argillaceous, slightly sandy
	32'- 40'	Clay, gray, silty
	40'- 50'	Sand, colorless and very light gray, coarse to fine, subrounded to angular
	50'- 68'	Gravel, varicolored; sand, colorless and very light gray, coarse to fine, subrounded to angular
	68'- 69'	Clay, dark orange and brown, gravely, sandy

SW38 W-27839 location: NW,NW,NE,NE, Sec. 32, T70N, R41W Fremont Co.
elevation: 960' depth: 58' SW38U casing: 0'-35' of 2"
35'-38' of 2" slotted
SW38L casing: 0'-50' of 2"
50'-55' of 2" screen

log: Quaternary	0'- 2'	Topsoil (driller's log)
	2'- 5'	Clay, yellow-brown silty (driller's log)
	5'- 17'	Silt, yellow, argillaceous
	17'- 20'	Silt, yellow, argillaceous, calcareous
	20'- 26'	Silt, orange, very light gray, argillaceous, calcareous
	26'- 30'	Clay, very light gray, calcareous, silty
	30'- 32'	Clay, very light gray, calcareous, silty; silt, argillaceous
	32'- 34'	Clay, very light gray, calcareous, silty; silt, orange, argillaceous sand, colorless, coarse to fine
	34'- 40'	Sand, colorless, varicolored, coarse to fine; gravel
	40'- 56'	Sand, colorless, varicolored, coarse to fine; gravel, subrounded to subangular
Pleistocene	56'- 58'	Gravel, gray; till?, gray unoxidized, leached?

SW35 W-27835 location: NE,NE,SW,NE, Sec. 20, T72N, R38W Montgomery Co.

elevation: 1038' depth: 33' SW35U casing: 0'-14' of 2"
14'-17' of 2" slotted
SW35L casing: 0'-22' of 2"
22'-27' of 2" slotted

log: Quaternary
0'- 5' Topsoil and clay, gray (driller's log)
5'- 12' Silt, orange-gray, very argillaceous
12'- 15' Silt, orange-gray, very argillaceous; sand, coarse; gravel, varicolored
15'- 17' Sand, colorless and orange, coarse to fine, clean
17'- 20' Sand, colorless, yellow, orange, dark, coarse to medium
20'- 30' Sand, colorless, yellow, orange, dark, coarse to medium; gravel
Pennsylvanian Virgil Series
30'- 33' Limestone, brown to yellow, with iron oxide

SW34 W-27834 location: NE,NE,NE,NW, Sec. 36, T74N, R38W Pottawattamie Co.
elevation: 1073' depth: 101' SW34U casing: 0'-20' of 2"
20'-25' of 2" screen
SW34L casing: 0'-34' of 2"
34'-39' of 2" screen

log: Quaternary
0'- 3' Fill and topsoil (driller's log)
3'- 5' Clay, dark gray (driller's log)
5'- 9' Clay, gray, yellow-gray, silty
9'- 11' Silt, orange, argillaceous
11'- 15' Silt, gray, yellow-gray, argillaceous
15'- 18' Sand, colorless, yellow, orange, dark, medium to fine and coarse, quartz
18'- 24' Sand, colorless, yellow, orange, dark, medium to fine and coarse, quartz; gravel, partly argillaceous
24'- 31' Gravel; sand, colorless, yellow, orange, dark, medium to fine and coarse, quartz
31'- 40' Sand, colorless, yellow, orange, dark, medium to fine and coarse, quartz, gravel
40'- 55' Sandstone; gravel; dolostone (gravel?), very light gray, silt-grade -- possibly clast broken up by drilling
55'- 60' Gravel, igneous & dolostone rocks; sand
Cretaceous Dakota
60'-100' Sandstone, colorless, orange, medium to coarse and fine, quartz
100'-101' Sandstone, yellow-brown and tan, fine to medium (driller's log)

SW16 W-27715 location: NW,NW,NW,NW,NW, Sec. 30, T74N, R37W Cass Co.
elevation: 1090' depth: 156' SW16U casing: 0'-37' of 2"
37'-42' of 2" slotted
SW16L casing: 0'-59' of 2"
59'-70' of 2" slotted

log: Quaternary
0'- 5' Topsoil and clay, dark brown, silty (driller's log)
5'- 9' Clay, orange-brown, mottled, silty
9'- 17' Silt, yellow, argillaceous
17'- 23' Silt, yellow, mottled orange, argillaceous

	23'- 29'	Clay, yellow, silty
	29'- 43'	Sand, colorless, varicolored, medium to coarse to fine, subrounded; gravel
Pleistocene	43'- 53'	Sand, colorless, orange, pink, fine to medium, subangular, quartz
	53'- 54'	Sand, colorless, varicolored, coarse to fine; gravel
	54'- 56'	Silt, yellow argillaceous; gravel
	56'- 59'	Clay, yellow and gray, silty, sandy
	59'- 67'	Gravel, varicolored; sand, colorless, yellow, orange, fine to medium, subrounded
	67'- 70'	Gravel, varicolored; sand, silty, argillaceous
	70'- 72'	Clay, orange, silty, sandy
Pennsylvanian	72'- 75'	Shale, gray, silty, sandy, unoxidized, leached
	75'- 96'	Shale, gray, silty
	96'- 98'	Shale, gray, silty, with siderite
	98'-104'	Shale, gray, silty; sandstone, colorless, orange, fine to coarse
	104'-105'	Siderite, brown, crystalline, medium to fine
	105'-113'	Shale, gray, very sandy
	113'-130'	Shale, gray, sandy, silty
	130'-145'	Shale, gray, lumpy, silty
	145'-146'	Chert, very light gray; shale, gray, lumpy, silty
	146'-147'	Chert, very light gray; siderite, crystalline
	147'-148'	Siderite, argillaceous
	148'-150'	Shale, gray, silty, calcareous
	150'-152'	Shale, gray, silty, calcareous; limestone, dark gray, silt-grade
	152'-154'	Limestone, medium light gray, silt-grade partly argillaceous
	154'-156'	Shale, green, calcareous

SW33 W-27753 location: NW,NW,NE,SE, Sec. 23, T76N, R37W Cass Co.
elevation: 1142' depth: 68' SW33U casing: 0'-40' of 2"
40'-45' of 2" screen
SW33L casing: 0'-60' of 2"
60'-65' of 2" screen

log: Quaternary	0'- 2'	Topsoil (driller's log)
	2'- 12'	Silt, yellow argillaceous
	12'- 15'	Silt, very light gray and orange, very argillaceous
	15'- 20'	Sand, colorless, orange, dark (heavy), coarse to fine, partly with argillaceous cement
	20'- 22'	Silt, gray and yellow, very argillaceous
	22'- 35'	Silt, gray, with trace hard sand
	35'- 42'	Gravel, colorless, varicolored; sand, fine
	42'- 52'	Silt, gray, argillaceous, calcareous
	52'- 54'	Silt, medium dark gray, argillaceous
Pleistocene	54'- 59'	Till, gray, unoxidized, unleached
	59'- 66'	Sand, colorless, yellow, coarse to medium; gravel, quartz, trace igneous, granite?; gravel, light gray, silt-grade limestone rocks
Pennsylvanian Kansas City Group	66'- 68'	Limestone, light gray, silt-grade

APPENDIX II

Water Levels in Alluvial Monitoring Wells

Water levels in Geological Survey Bureau alluvial monitoring wells
(Locations shown on Figure 1.)

(Water levels in feet below land surface)

Well No.	Screened Interval	7/21/86	8/06/86	8/07/86	8/12/86	8/13/87	10/23/86	12/08/86	12/09/86	12/24/86
SW36U	40'-44'		12.58				8.47		9.53	
SW36L	57'-62'		10.64				8.20		9.17	
SW38U	35'-38'					18.48	18.35		18.06	
SW38L	50'-55'					18.39	18.30		18.02	
SW35U	14'-17'		7.87				8.30		6.55	
SW35L	22'-27'		8.01				5.02		6.46	
SW34U	20-'25'		6.30				3.75		5.47	
SW34L	34'-39'		6.39				3.80		5.54	5.94
SW16U	37'-42'	16.13		17.54	18.09		13.80		16.97	
SW16L	59'-70'	16.02		17.48	17.96		13.75		16.88	17.15
SW33U	35'-40'		11.14				10.15	11.70		
SW33L	60'-65'		13.78				10.50	11.88		

Well No.	Screened Interval	1/10/87	1/25/87	2/05/87	2/10/87	2/25/87	3/10/87	3/25/87	4/01/87	4/10/87
SW36U	40'-44'			10.52					10.40	
SW36L	57'-62'			10.20					10.11	
SW38U	35'-38'			19.10					17.10	
SW38L	50'-55'			19.05					17.07	
SW35U	14'-17'			8.55					7.80	
SW35L	22'-27'			8.42					7.76	
SW34U	20'-25'			7.10					6.01	
SW34L	34'-39'	6.68	6.87	7.20	7.29	7.55	7.29	6.64	6.31	5.64
SW16U	37'-42'			18.65					16.96	
SW16L	59'-70'	17.88	18.17	18.60	18.59	18.85	18.59	17.86	17.16	15.98
SW33U	35'-40'			13.30					12.68	
SW33L	60'-65'			13.30					12.28	

(Water levels in feet below land surface)

Well No.	Screened Interval	4/25/87	5/01/87	5/10/87	5/21/87	5/25/87	6/01/87	6/10/87	6/25/87	7/10/87
SW36U	40'-44'				5.95		2.12			
SW36L	57'-62'				8.48		3.03			
SW38U	35'-38'		15.92		16.93		12.46			
SW38L	50'-55'		15.83		16.89		12.52			
SW35U	14'-17'		6.41		6.52		2.81			
SW35L	22'-27'		6.39		6.45		2.74			
SW34U	20'-25'		5.21		5.62		2.06			
SW34L	34'-39'	5.17	5.36	5.86	5.69	5.00	2.11	3.97	5.47	3.57
SW16U	37'-42'		15.65		17.15					
SW16L	59'-70'	15.15	15.55	16.44	17.05	16.57	11.62	13.60	15.84	14.64
SW33U	35'-40'		12.05		12.61		11.20			
SW33L	60'-65'		12.20		12.79		11.15			

Well No.	Screened Interval	7/25/87	8/03/87	8/10/87	8/25/87	8/26/87	8/28/87	8/30/87	9/01/87	9/03/87
SW36U	40'-44'		5.67							
SW36L	57'-62'		6.70							
SW38U	35'-38'		16.95							
SW38L	50'-55'		16.95							
SW35U	14'-17'		4.90							
SW35L	22'-27'		4.82							
SW34U	20'-25'		4.90			4.72	4.39	4.84	5.14	5.44
SW34L	34'-39'	5.30	4.80	5.03	5.49	4.78	4.46	4.89	5.20	5.50
SW16U	37'-42'		16.68			16.68	15.90	16.05	16.25	16.53
SW16L	59'-70'	15.60	14.90	16.16	16.67	16.58	15.82	15.97	16.16	16.42
SW33U	35'-40'									
SW33L	60'-65'									

(Water levels in feet below land surface)

Well No.	Screened Interval	9/05/87	9/07/87	9/10/87	9/24/87	10/06/87	10/10/87	10/12/87	10/25/87	11/04/87
SW36U	40'-44'					6.97				
SW36L	57'-62'					8.50				
SW38U	35'-38'					17.05				
SW38L	50'-55'					16.95				
SW35U	14'-17'									
SW35L	22'-27'					5.32				
SW34U	20'-25'	5.69	5.44					6.04		
SW34L	34'-39'	5.75	5.51	5.81	5.08		6.16	6.13	6.57	6.98
SW16U	37'-42'	16.84	16.50					16.80		
SW16L	59'-70'	16.74	16.40	16.60	15.05		16.57	16.70	17.36	
SW33U	35'-40'							13.28		
SW33L	60'-65'							10.78		

Well No.	Screened Interval	11/29/87	12/10/87	12/25/87
SW36U	40'-44'			
SW36L	57'-62'			
SW38U	35'-38'			
SW38L	50'-55'			
SW35U	14'-17'			
SW35L	22'-27'			
SW34U	20'-25'			
SW34L	34'-39'			
SW16U	37'-42'			
SW16L	59'-70'	18.20	17.97	18.18
SW33U	35'-40'			
SW33L	60'-65'			

APPENDIX III

Background Pesticide Data - Municipal Alluvial Wells in the Nishnabotna River Basin

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

LOCATION	DATE	atrazine AAtrex	cyanazine Bladex	metolachlor Dual	alachlor Lasso	metribuzin Sencor	trifluralin Treflan
Avoca #2	06/19/86	0.29	<0.1	<0.1	<0.1	<0.1	<0.1
Avoca #2	08/20/86	0.53	<0.1	<0.1	<0.1	<0.1	<0.1
Avoca (F)	01/07/87	0.26	<0.2	<0.2	<0.2	<0.2	<0.2
Hancock #6	08/06/85	<0.1	<0.1	<0.1	<0.1	<0.05	<0.05
Hancock #6	08/20/86	0.18	<0.1	<0.1	<0.1	<0.1	<0.1
Hancock (F)	02/23/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Oakland #11	08/26/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Oakland (F)	05/18/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Carson #2	06/09/86	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
Carson #2	07/20/86	<0.1	<0.1		<0.1	<0.1	<0.1
Carson (F)	12/01/86	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Macedonia #2	08/06/85	0.24	<0.1	<0.1	<0.1	<0.05	<0.05
Macedonia #1	08/20/86	0.23	<0.1	<0.1	<0.1	<0.1	<0.1
Macedonia (F)	06/17/87	0.31	<0.2	0.64	0.87	<0.2	<0.2
Hendersen #2	08/21/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Henderson (F)	06/02/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Hastings #1	08/08/85	<0.1	<0.1	<0.1	<0.1	<0.05	<0.05
Hastings #1	08/19/86	0.16	<0.1	<0.1	<0.1	<0.1	<0.1
Malvern #11	06/19/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Malvern (F)	06/17/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver City #3	06/18/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Siver City (F)	09/22/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Tabor #1	08/15/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tabor (F)	09/21/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Randolph #3	08/14/85	<0.1	<0.1	<0.1	<0.1	<0.05	<0.05
Randolph (F)	09/22/87	0.88	<0.2	<0.2	<0.2	<0.2	<0.2
Riverton #2	08/21/85	<0.1	<0.1	<0.1	<0.1	<0.05	<0.05
Riverton #2	08/14/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Riverton (F)	08/22/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Shenandoah #17	08/14/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shenandoah #25	08/14/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Essex #5	08/14/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Essex (F)	03/17/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Marne #3	08/06/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Marne (F)	01/26/87	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

LOCATION	DATE	dicamba Banvel	chloramben Amiben	2,4-D	propachlor Ramrod	fonofos Dyfonate	carbofuran Furadan
Avoca #2	06/19/86	<0.1	<0.1	<0.1		<0.1	<0.1
Avoca #2	08/20/86				<0.1		
Avoca (F)	01/07/87		<0.2	<0.2	<0.2	<0.2	<0.2
Hancock #6	08/06/85	<0.07		<0.07		<0.1	
Hancock #6	08/20/86				<0.1		
Hancock (F)	02/23/87		<0.2	<0.2	<0.2	<0.2	<0.2
Oakland #11	08/26/86				<0.1		
Oakland (F)	05/18/87		<0.2	<0.2	<0.2	<0.2	<0.2
Carson #2	06/09/86	<0.1	<0.1	<0.1		<0.1	<0.1
Carson #2	07/20/86				<0.1		
Carson (F)	12/01/86		<0.2	<0.2	<0.2	<0.2	<0.2
Macedonia #2	08/06/85	<0.07		<0.07		<0.1	
Macedonia #1	08/20/86				<0.1		
Macedonia (F)	06/17/87		<0.2	<0.2	<0.2	<0.2	<0.2
Hendersen #2	08/21/86	<0.1	<0.1	<0.1		<0.1	<0.1
Henderson (F)	06/02/87		<0.2	<0.2	<0.2	<0.2	<0.2
Hastings #1	08/08/85	<0.07				<0.1	
Hastings #1	08/19/86				<0.1		
Malvern #11	06/19/86	<0.1	<0.1	<0.1		<0.1	<0.1
Malvern (F)	06/17/87		<0.2	<0.2	<0.2	<0.2	<0.2
Silver City #3	06/18/86	<0.1	<0.1	<0.1		<0.1	<0.1
Siver City (F)	09/22/87		<0.2	<0.2	<0.2	<0.2	<0.2
Tabor #1	08/15/86	<0.1	<0.1	<0.1		<0.1	<0.1
Tabor (F)	09/21/87		<0.2	<0.2	<0.2	<0.2	<0.2
Randolph #3	08/14/85	<0.07		<0.07		<0.1	
Randolph (F)	09/22/87		<0.2	<0.2	<0.2	<0.2	<0.2
Riverton #2	08/21/85	<0.07		<0.07		<0.1	
Riverton #2	08/14/86	<0.1	<0.1	<0.1		<0.1	<0.1
Riverton (F)	08/22/87		<0.2	<0.2	<0.2	<0.2	<0.2
Shenandoah #17	08/14/86	<0.1	<0.1	<0.1		<0.1	<0.1
Shenandoah #25	08/14/86	<0.1	<0.1	<0.1		<0.1	<0.1
Essex #5	08/14/86	<0.1	<0.1	<0.1		<0.1	<0.1
Essex (F)	03/17/87		<0.2	<0.2	<0.2	<0.2	<0.2
Marne #3	08/06/87						
Marne (F)	01/26/87		<0.2	<0.2	<0.2	<0.2	<0.2

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

terbufos Counter	chlorpyrifos Lorsban	ethoprop Mocap	phorate Thimet	butylate Sutan	sulprofos Bolstar	pendimethalin Prowl	diazinon Diazinon
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
			<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
			<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.1		<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
			<0.1				
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
			<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
			<0.1				
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
<0.1	<0.1	<0.1	<0.1				
<0.1	<0.1	<0.1	<0.1				
<0.1	<0.1	<0.1	<0.1				
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
				<0.1			
<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

APPENDIX IV

Pesticide Monitoring Results

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

LOCATION	DATE	atrazine AAtrex	cyanazine Bladex	metolachlor Dual	alachlor Lasso	metribuzin Sencor	trifluralin Treflan
Avoca #3	5/04/87	0.39	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	0.17	<0.1	<0.1	<0.1	<0.1	<0.1
	7/06/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Oakland #8	5/04/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Oakland #11	5/04/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	0.16	1.7	<0.1	<0.1	<0.1	<0.1
Hendersen #2	6/02/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shenandoah #18	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shenandoah #26	3/16/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Malvern #11	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/08/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Elliott #1	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ES1	6/01/87	0.90	1.40	0.84	0.39	<0.1	<0.1
	7/01/87	0.13	<0.1	<0.1	<0.1	<0.1	<0.1
ES2	6/01/87	4.15	3.39	1.20	0.35	0.28	<0.1
	7/01/87	0.35	0.18	<0.1	<0.1	<0.1	<0.1
WS1	6/01/87	1.3	4.10	<0.1	0.35	0.28	<0.1
	7/01/87	0.21	0.11	<0.1	<0.1	<0.1	<0.1
WS2	6/01/87	3.7	7.10	0.93	0.73	0.33	<0.1
	7/01/87	0.33	0.16	<0.1	<0.1	<0.1	<0.1

LOCATION	DATE	propachlor Ramrod	fonofos Dyfonate	terbufos Counter	chlorpyrifos Lorsban	ethoprop Mocap	phorate Thimet
	(all concentrations are in ug/l) (concentrations above detection limits are underlined)						
Avoca #3	5/04/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/06/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Oakland #8	5/04/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Oakland #11	5/04/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Henderson #2	6/02/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shenandoah #18	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Shenandoah #26	3/16/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Malvern #11	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/08/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Elliott #1	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ES1	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
ES2	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS1	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS2	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

butylate Sutan	sulprofos Bolstar	pendimethalin Prowl	diazinon Diazinon	dimethoate Dimethoate	parathion	malathion	simazine Princep
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.98
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

LOCATION	DATE	atrazine AAtrex	cyanazine Bladex	metolachlor Dual	alachlor Lasso	metribuzin Sencor	trifluralin Treflan
SW34U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW34L	8/06/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW16U	8/12/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW16L	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW33U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW33L	8/06/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW36U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW36L	8/06/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW38U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW38L	8/13/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW35U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW35L	8/06/86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

propachlor Ramrod	fonofos Dyfonate	terbufos Counter	chlorpyrofos Lorsban	ethoprop Mocap	phorate Thimet	butylate Sutan	sulprofos Bolstar
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1						<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1						<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1						<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1						<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

(all concentrations are in ug/l) (concentrations above detection limits are underlined)

LOCATION	DATE	pendimethalin Prowl	diazinon Diazinon	dimethoate Dimethoate	parathion	malathion
SW34U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW34L	8/06/86	<0.1				
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW16U	8/12/86					
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW16L	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW33U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW33L	8/06/86	<0.1				
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW36U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW36L	8/06/86	<0.1				
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW38U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW38L	8/13/86		<0.1			
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW35U	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
SW35L	8/06/86	<0.1				
	5/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	6/01/87	<0.1	<0.1	<0.1	<0.1	<0.1
	7/01/87	<0.1	<0.1	<0.1	<0.1	<0.1