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Occurrence of Nitrate in Groundwater, Grand Forks: Results of 1989/90 Sampling Programs

by

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Executive Summary

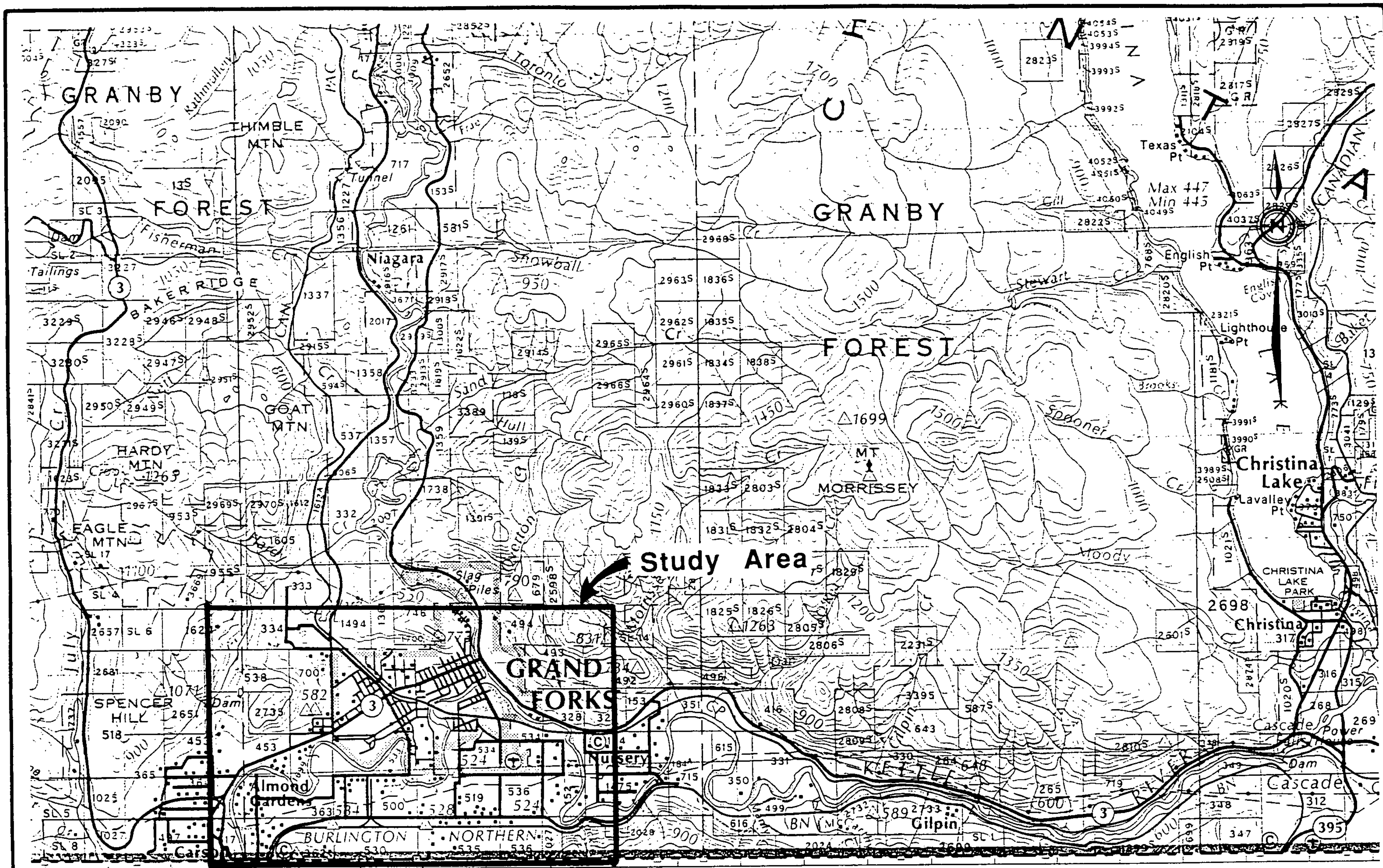
Initial field survey and sampling in Grand Forks indicates 3 areas of nitrate contamination in the regional aquifer: in the area south of the airport, in the Nursery area, and near North Fork Rd. along the western limits of the City of Grand Forks. Nitrate concentrations in these areas are elevated and locally exceed the drinking water limit of 10 mg/L NO_3-N. Nitrate-nitrogen concentrations in the aquifer is log-normally distributed and averages 5.4 mg/L. Nitrate appears to be derived mostly from surface non-point application of inorganic fertilizers on vegetable fields. The high nitrate areas correlate with areas of vegetable farming. High nitrate levels are generally associated with high specific conductance, total dissolved solids, calcium and magnesium (hardness), chloride, and sulfate in groundwater. Nitrate, calcium, magnesium, chloride, and sulfate, common constituents in inorganic fertilizers, have probably leached into the aquifer. Denitrification may be occurring at depth in the aquifer. Implications of nitrate contamination movement towards the south into the USA appears negligible because regional groundwater flow in the aquifer is away from the border. Further monitoring and investigation in this area are required to better understand nitrate occurrence and behavior in groundwater for formulating effective strategies to protect the aquifer.

Introduction

In 1989, investigation of groundwater contamination by nitrate (NO_3) in the Grand Forks area was initiated under the Water Quality Monitoring and Assessment Program. The study area, located in the Kettle River valley, covers the Grand Forks Irrigation District (GFID), Covert Irrigation District (CID), Sion Improvement District (SID), and the City of Grand Forks (Figures 1 and 2). Nitrate derived from fertilizer application and from septic systems can potentially impact water quality of the aquifer (Figure 3). The area was chosen for investigation for following reasons:

- many of the local residents rely on groundwater as a source of domestic and irrigation supply,
- the regional aquifer underlying the area is unconfined and highly productive and is therefore susceptible to contamination from surface sources,
- agriculture is a major land-use activity there,
- homes outside of the Grand Forks city limits are on septic systems,
- there are reports of elevated NO_3 in groundwater.

Elevated levels of NO_3 in the range of up to 8.75 mg/L were detected in the newly drilled GFID wells in 1987 (Wei, 1987 and 1988). Historic data (38 sites) indicate that 18% of the sampled wells in the study area had nitrate- and nitrite nitrogen ($[NO_2+NO_3]$-N) of >10 mg/L (Sather, 1989). Forty-two percent had elevated



Province of British Columbia Ministry of Environment INVENTORY AND ENGINEERING BRANCH	TO ACCOMPANY REPORT ON **Location Map**	SCALE: VERT. .... HOR. 1: 100 000 DATE: April/92 M. Wei ENGINEER FILE No. .... DWG. No. Figure 1

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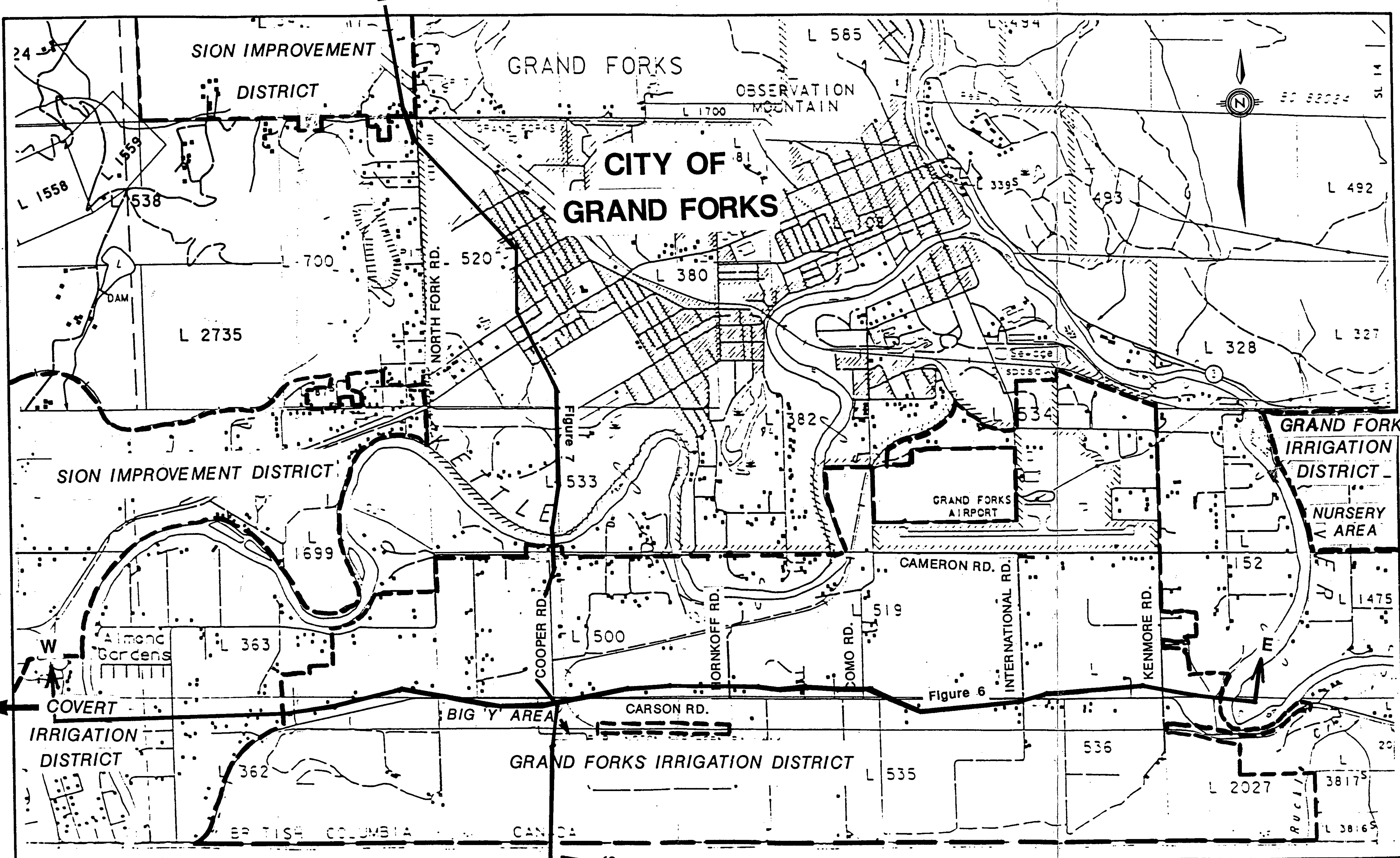

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WATER MANAGEMENT BRANCH

BOUNDARIES FOR GRAND FORKS AND COVERT IRRIGATION DISTRICTS AND SION IMPROVEMENT DISTRICT

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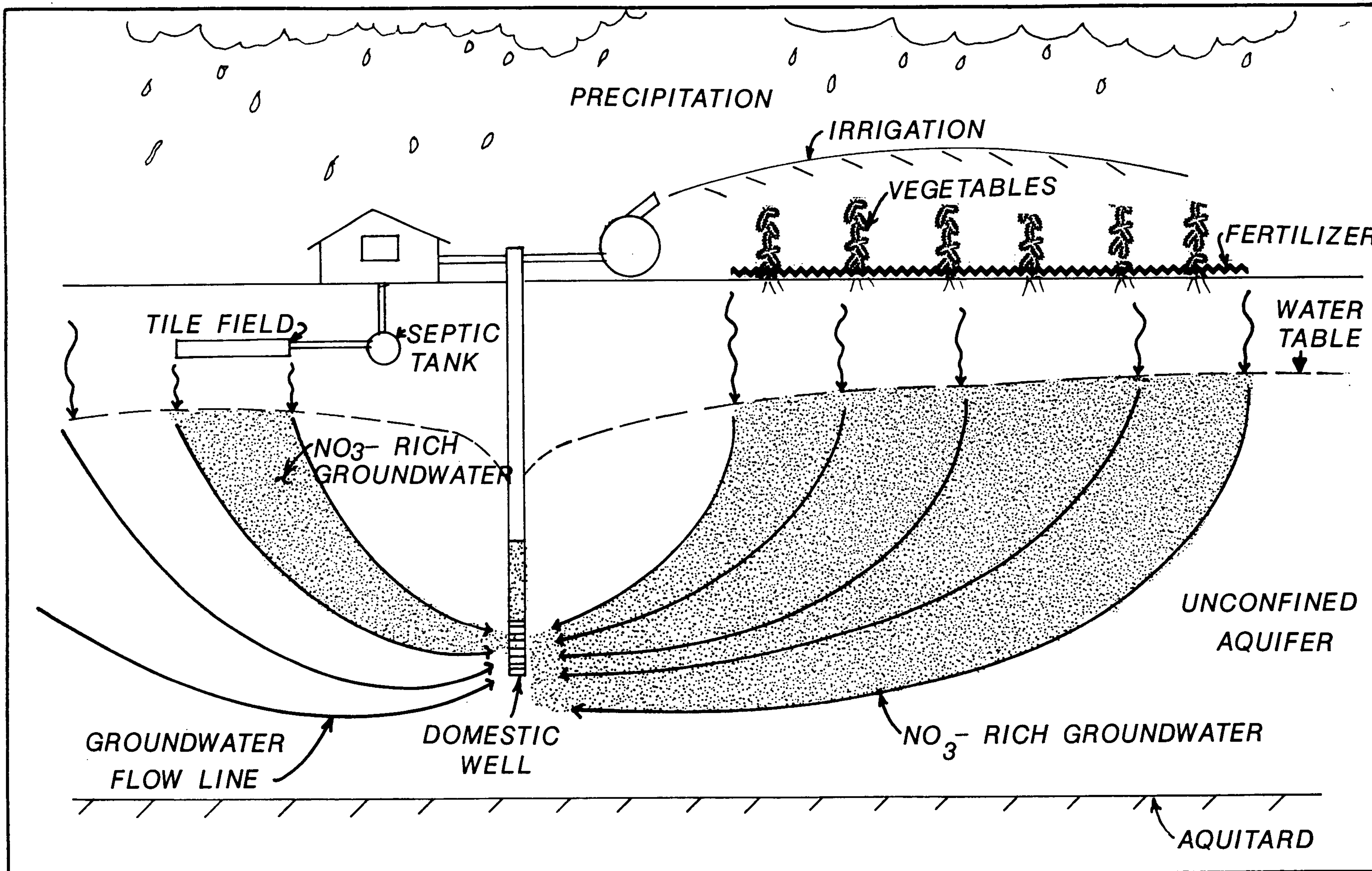
M. WEI	ENGINEER
FILE No. 0329563-A	DWG No. FIGURE 2



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WATER MANAGEMENT BRANCH

POTENTIAL SOURCES OF NITRATE CONTAMINATION, (SCHEMATIC), GRAND FORKS

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M. WEI ENGINEER	
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levels of $[NO_2+NO_3]$-N (> 5 mg/L). The drinking water limit for nitrate-nitrogen (NO_3-N) is 10 mg/L.

Purpose and Objectives of the Study

The nature and occurrence of nitrate in groundwater needs to be investigated and understood to formulate effective strategies for managing and protecting the aquifer. One such strategy is to establish water quality objectives for the area based on knowledge of the aquifer and potential sources of contaminants. Monitoring groundwater quality is also necessary to assess the effectiveness of any remediation strategies and to document water quality trends. Investigations may also identify possible groundwater contamination by other sources such as pesticide use for example.

The objectives of this report are to:

- present the results of initial sampling and monitoring conducted in 1989-90,
- correlate water quality with local land-use practice and hydrogeologic conditions,
- ascertain the sources (point or non-point sources, surface or non-surface sources, fertilizer or septic systems) and behavior of NO_3-N in groundwater, and
- recommend next steps for monitoring and investigation.

Results of subsequent monitoring carried out in 1991/92 will be the subject of a further report which is currently under preparation.

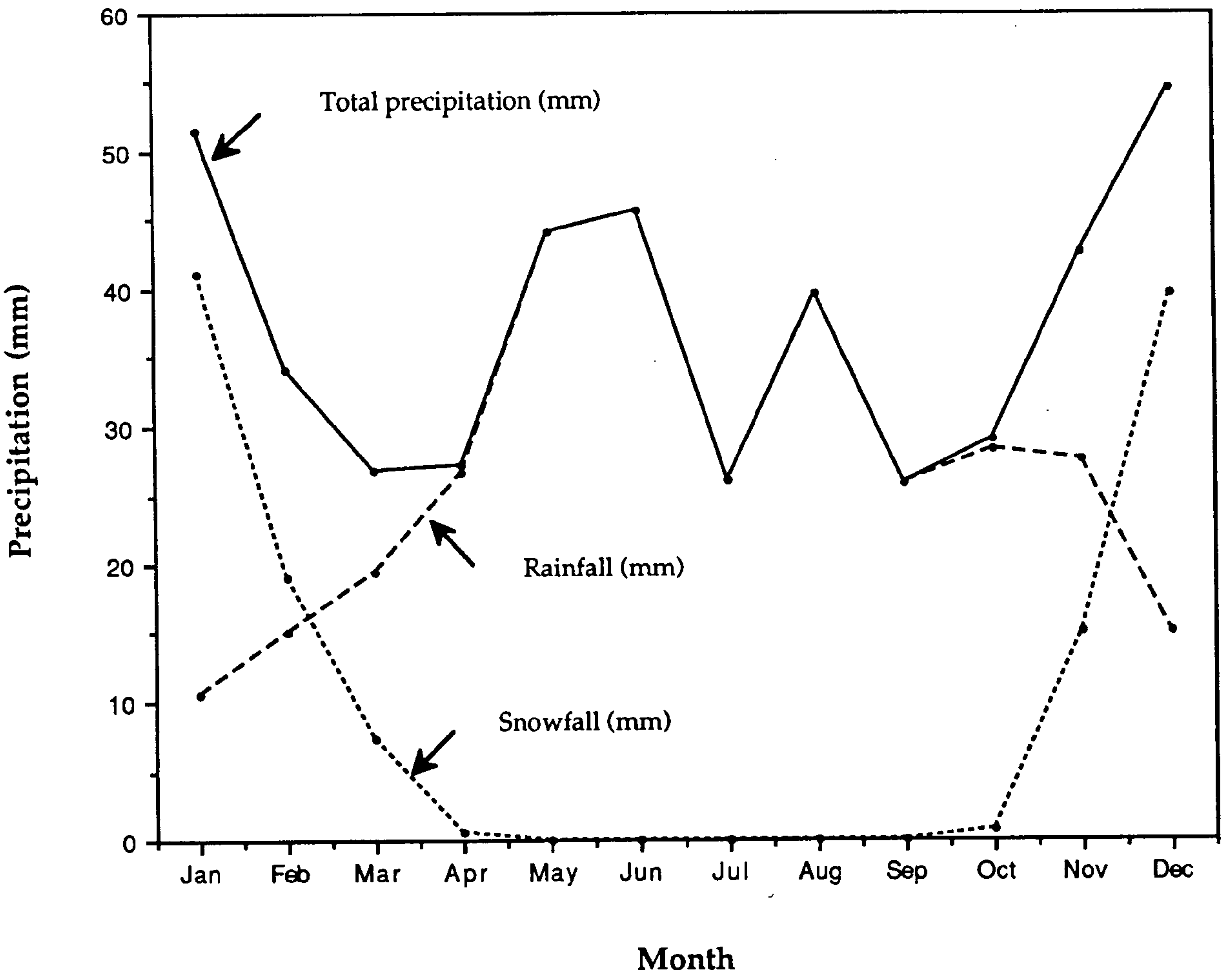
Hydrogeology and Groundwater Conditions

Grand Forks is situated in the Kettle River valley near the U.S. border, 325 miles (520 km) east of Vancouver (Figures 1 and 2). The area is semi-arid and normally receives 17.6 inches (447 mm) of precipitation annually (Figure 4). Much of the precipitation falls as snow during the winter months between October and February (*Canadian Climate Normals-Temperature and Precipitation, 1951-1980*).

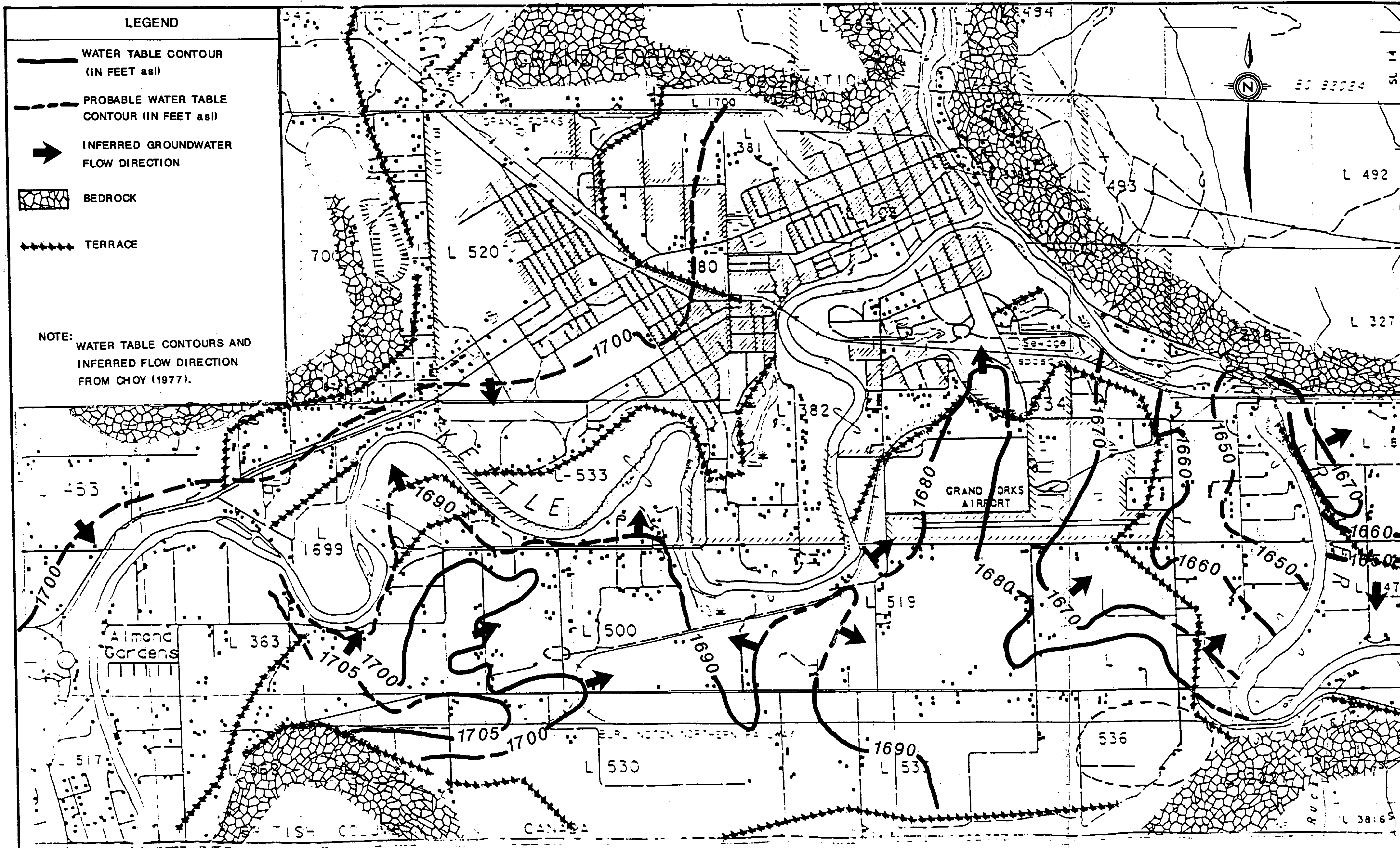
The Kettle River valley has been infilled with terraced glaciofluvial deposits (Figure 5). The deposits consist mostly of sand, gravel, silt, and clay. The maximum thickness of these deposits is unknown but reaches 405' (123m) based on available well records. Review of well records suggests that these deposits generally get progressively finer with depth and towards the east in the study area (Figures 6 and 7). The thick sand and gravel sections encountered in the SID and CID wells and in the GFID wells at the Big 'Y' area are largely absent in the Nursery area to the east.

The upper coarser section of the deposits, consisting mostly of sand and gravel with some clay and silt, forms a productive unconfined aquifer in the region. The aquifer supplies groundwater for domestic, irrigation, and industrial uses to the Grand Forks area. The City of Grand Forks, Sion Improvement District, Covert

Figure 4. Normal Precipitation, Grand Forks



Based on data from Canadian Climate Normals-Temperature and Precipitation, 1951-1980



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GRAND FORKS AREA
HYDROGEOLOGY OF THE GRAND FORKS AQUIFER

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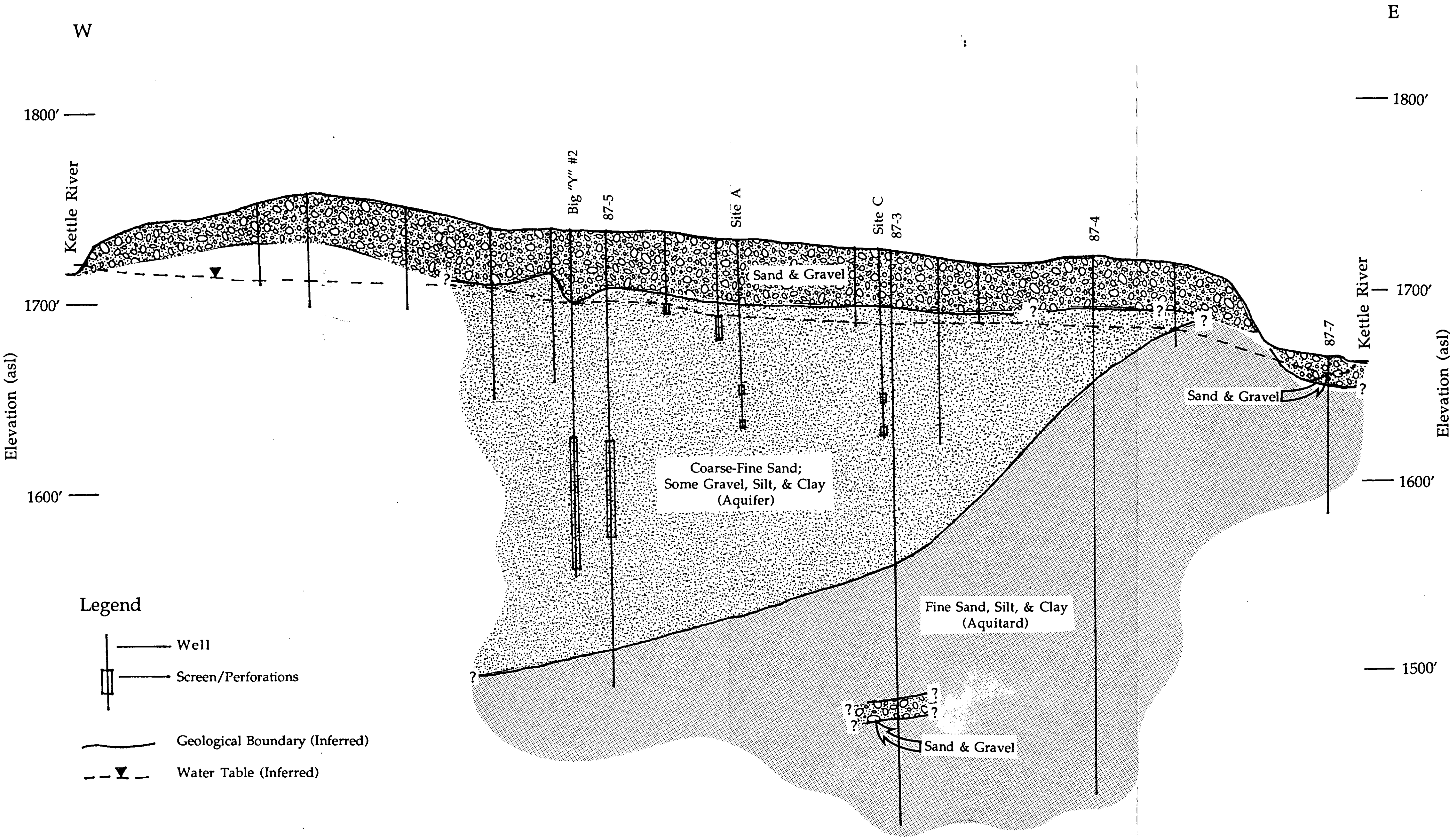

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Hydrogeological Cross-Section
Looking North along Carson Rd.
Grand Forks, B.C.

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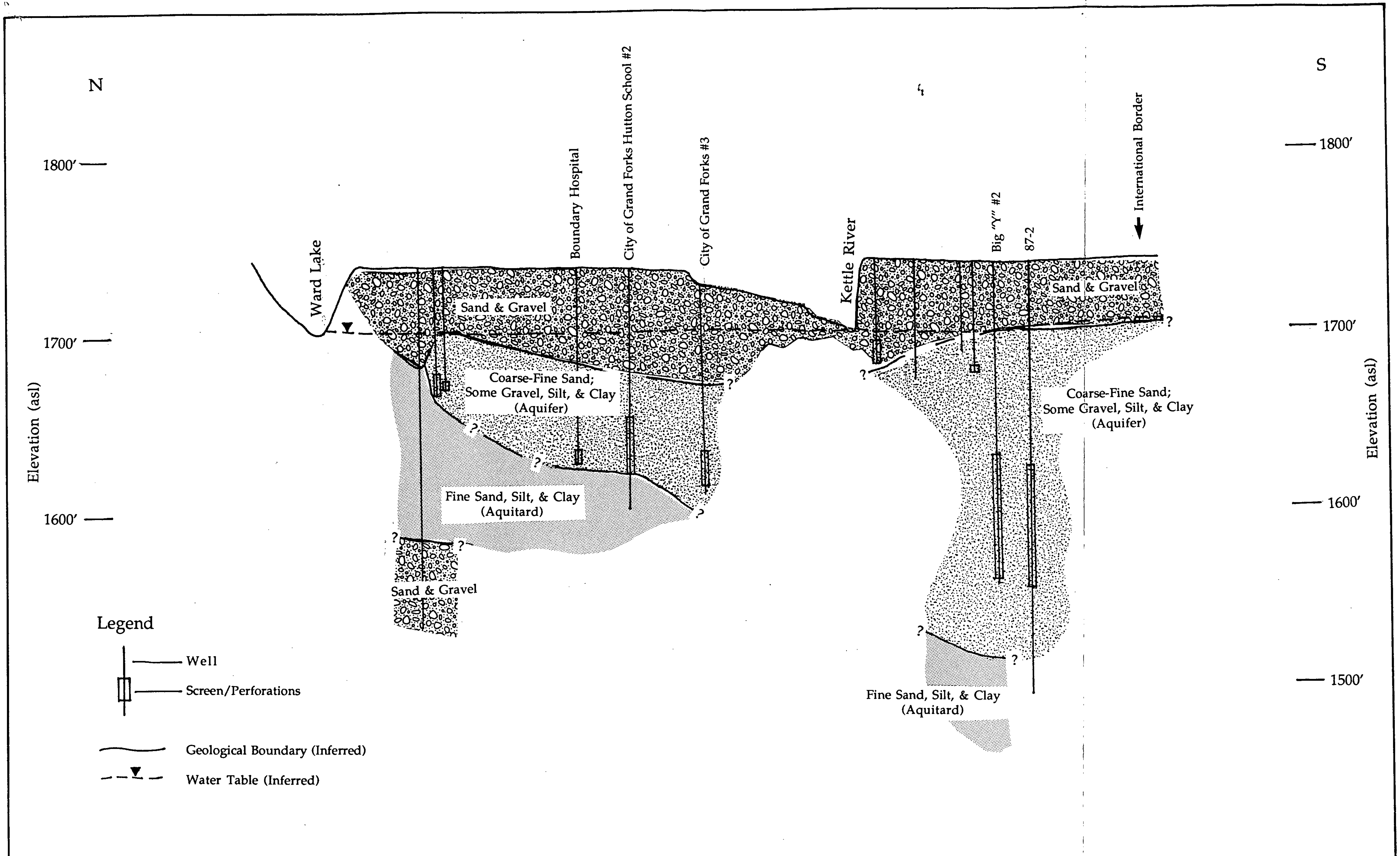
B



Province of British Columbia
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Water Management Branch

Hydrogeological Cross-Section Looking East
Grand Forks, B.C.

SCALE: VERT. 1:610
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DATE Sept/92

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FILE No. 82E/1 DWG No. Figure 7

Irrigation District, and recently, the Grand Forks Irrigation District all rely on groundwater for supply. Available well records show that more than 240 wells have been completed into the aquifer (Appendix A). However, many of the private domestic wells within the GFID are no longer in use since the GFID production wells came into production.

Aquifer transmissivity ranges up to 800,000 USgpd/ft (0.12 m^2/s) based on results of available pump tests of production wells. The aquifer is capable of supplying up to 2000 USgpm (125 L/s) to individual production wells.

The depth to water table is generally within 50′ (15 m) in the study area. The water table generally slopes towards the east and towards the Kettle River (Figure 5), indicative of regional groundwater flow directions. Recharge to the aquifer likely comes mainly from the Kettle River, from infiltration of precipitation, and irrigation return flow in the growing season. A hydrologic budget of the aquifer is shown in Figure 8. Recharge from the Kettle River is evident from similarity between the fluctuation of the river discharge and groundwater levels recorded in observation well no. 217 and from the hydraulic gradient direction in the aquifer (Figure 5 and 9). Much of this recharge seems to occur during spring freshet and implies that recharge from the Kettle River and from infiltration of precipitation are the most significant recharge mechanisms.

In the GFID area, a significant amount of recharge likely comes from the Kettle River to the west. Groundwater flows eastwards in the aquifer and eventually discharges back to the river downstream or flows as groundwater out of the study area.

Approach and Methodology

Initial Reconnaissance Survey

An initial field reconnaissance survey was conducted in May, 1989 to determine the areal extent of NO_3 occurrence in groundwater in the study area (Sather, 1989). One hundred wells were sampled and analyzed for temperature, specific conductance, pH, iron (Fe), chloride (Cl), alkalinity, hardness, and NO_3-N using a Beckman conductivity meter and Hach testing kits (model AL-94/AY and NI-11). The locations of the 100 sites are shown in Figure 10 (Kalyn, 1989). Information such as well depth was also recorded where available during the survey.

Long-term Monitoring of Domestic Wells and Nested Piezometers

Domestic Wells. From the reconnaissance survey, 14 domestic wells were then selected for monitoring temporal NO_3-N trends (Figure 11). The objective is to monitor groundwater quality in representative domestic wells over time to ascertain trends. The wells were selected to provide broad coverage of the study area.

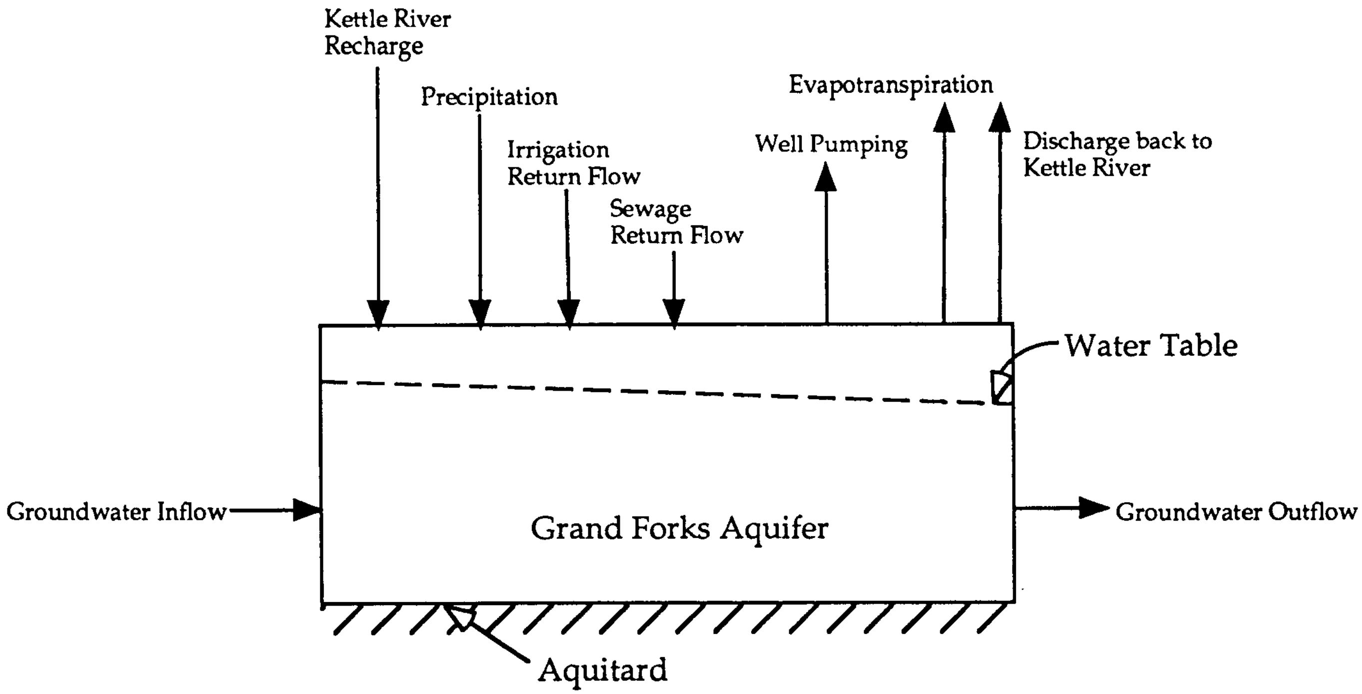


Figure 8. Hydrologic Budget of the Grand Forks Aquifer (Schematic)

Figure 9a. 1990 Month-End Hydrograph-Obs. Well No. 217

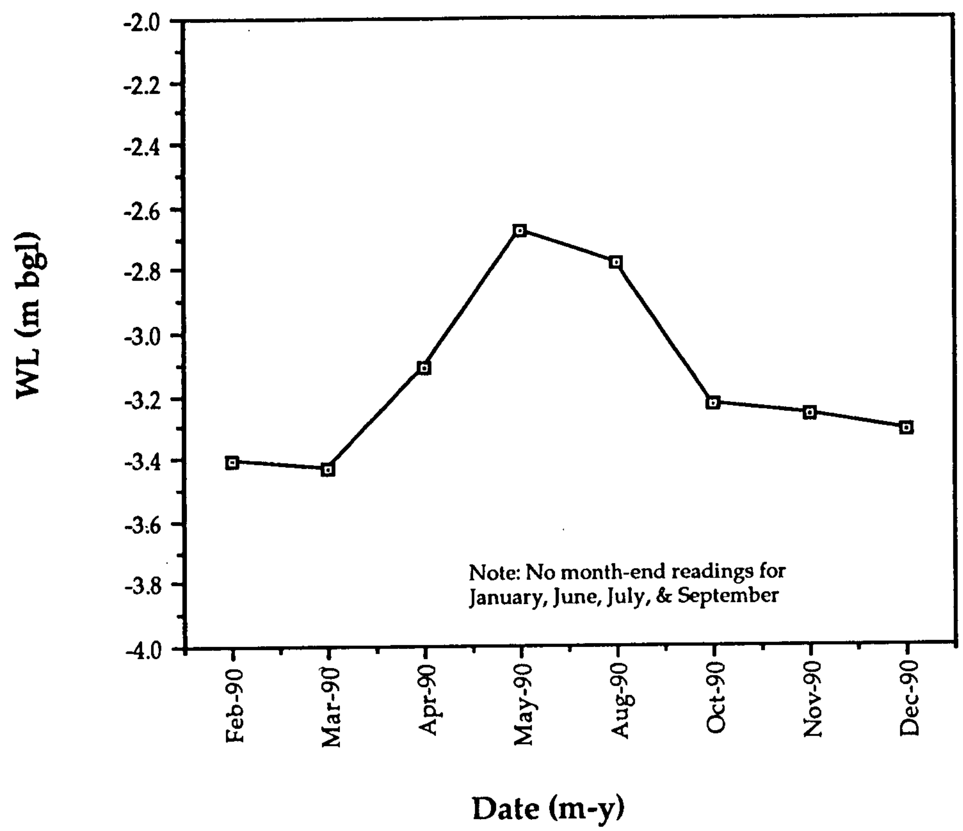
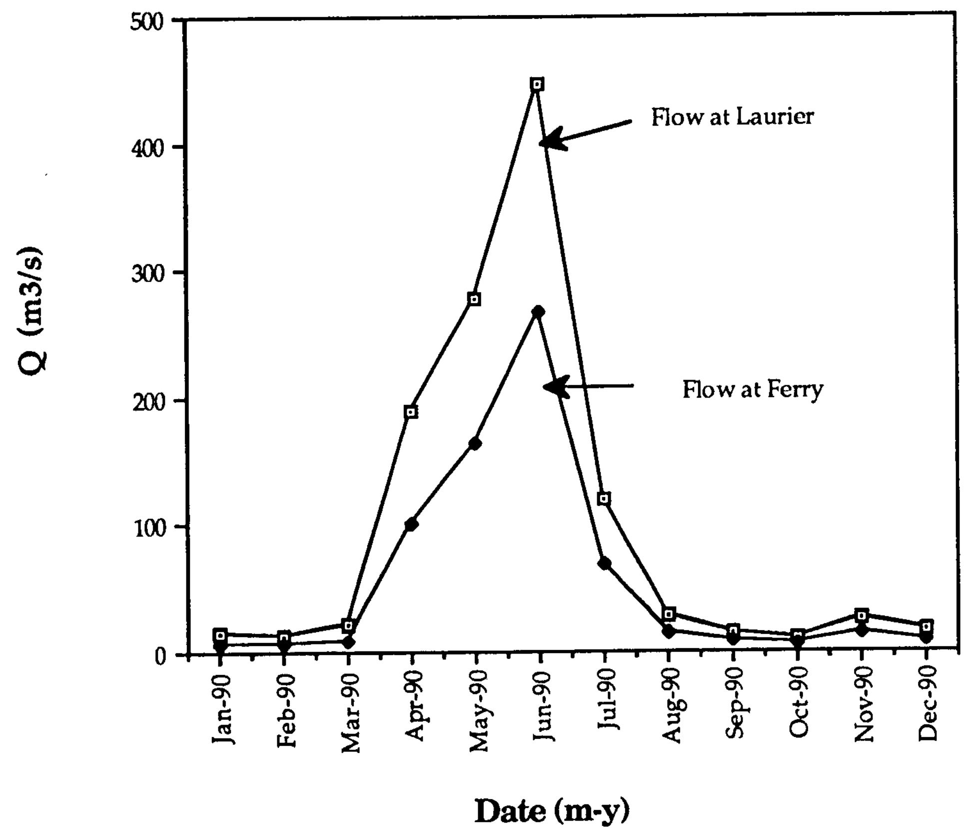
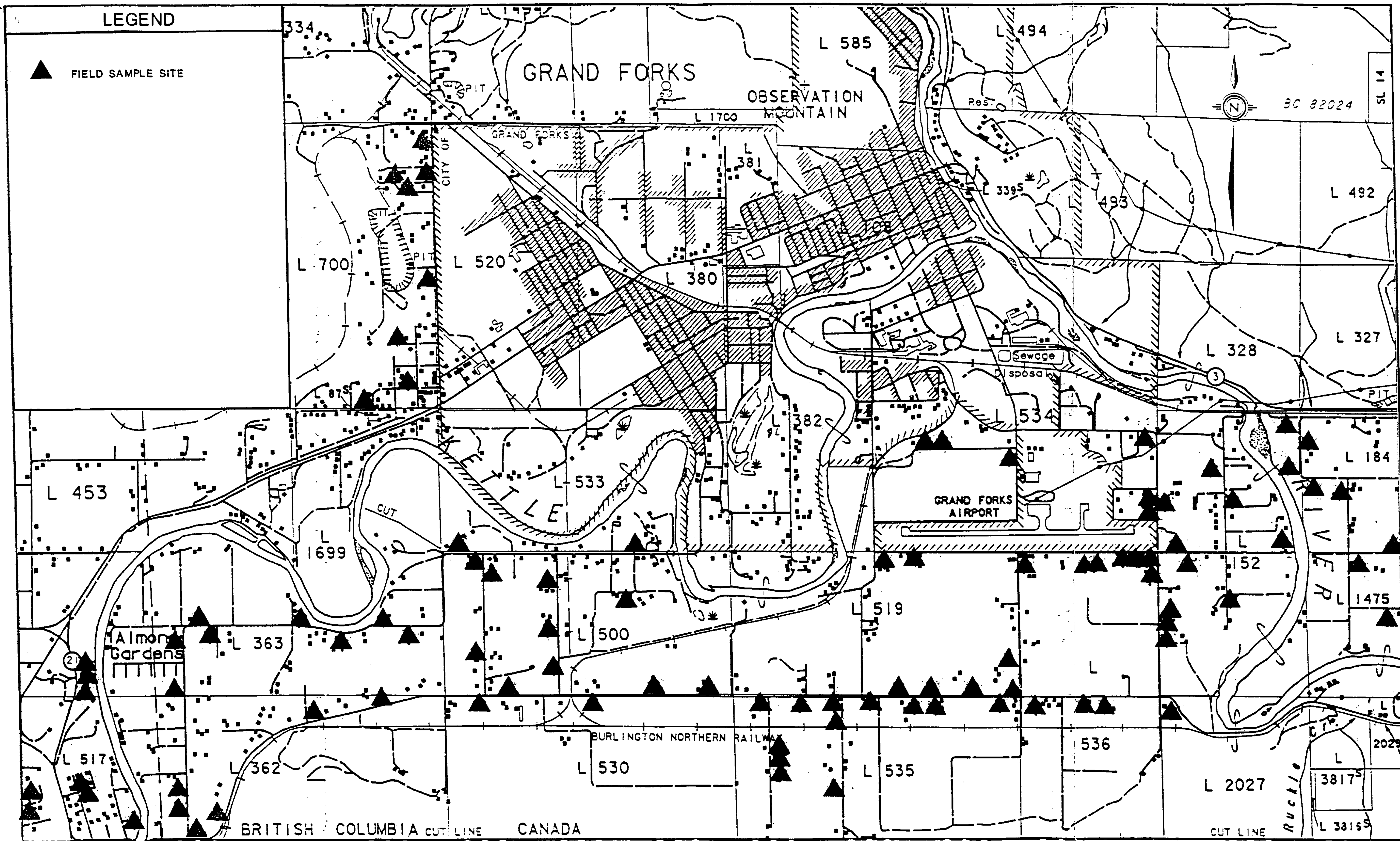
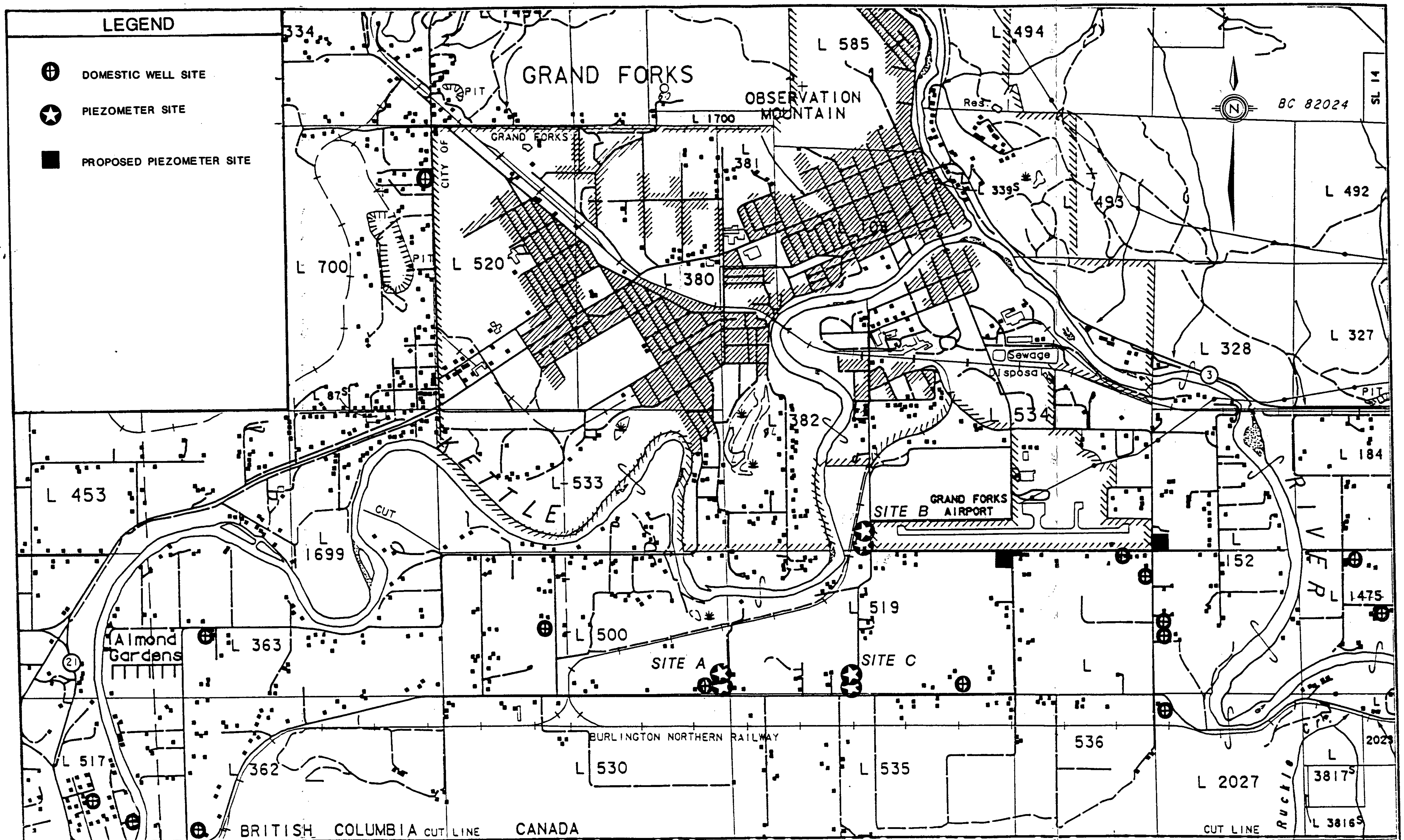


Figure 9b. 1990 Kettle River Flow





	Province of British Columbia Ministry of Environment and Parks WATER MANAGEMENT DIVISION GROUNDWATER SECTION	GRAND FORKS AREA FIELD SAMPLE SITES - MAY 1989	SCALE: 1 : 20 000 DATE: MARCH 1992 M. WEI ENGINEER FILE No. 0329563-A DWG No. FIGURE 10



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GROUNDWATER SECTION

GRAND FORKS AREA
GROUNDWATER MONITORING SITES

SCALE: 1 : 20 000	DATE MARCH 1992
M. WEI	ENGINEER
FILE No. 0329563-A	DWG No. FIGURE 11

Sampling and monitoring were focused in the GFID area where many individual domestic wells exist. The CID, SID, and the City of Grand Forks rely on community wells for domestic and irrigation use; the well density in these areas are lower (Figure 12). Production wells for the City of Grand Forks and the irrigation districts (Sion, Covert, and Grand Forks) were not monitored.

Nested Piezometers. Nested piezometers were constructed at 3 sites in late fall, 1989 to monitor nitrate behavior in groundwater at a local scale (Chwojka, 1991). The sites are centrally situated within the GFID (Figure 11). Piezometers were completed to approximately 40′ (12 m), 60′ (18 m), 80′ (24 m), and 100′ (30 m) below ground at all the sites. A detailed description of drilling and piezometer construction is found in Chwojka (1991) and will not be reiterated here.

Sampling Methodology

The piezometers and 14 domestic wells were sampled for NO_3 and other chemical parameters in 1989. The type of analysis is shown below in Table 1; the analytical results are shown in Appendix B.

Table 1. Type of Analysis for Groundwater Sampling

Domestic Wells	Piezometers
General Ions	General Ions & Metals

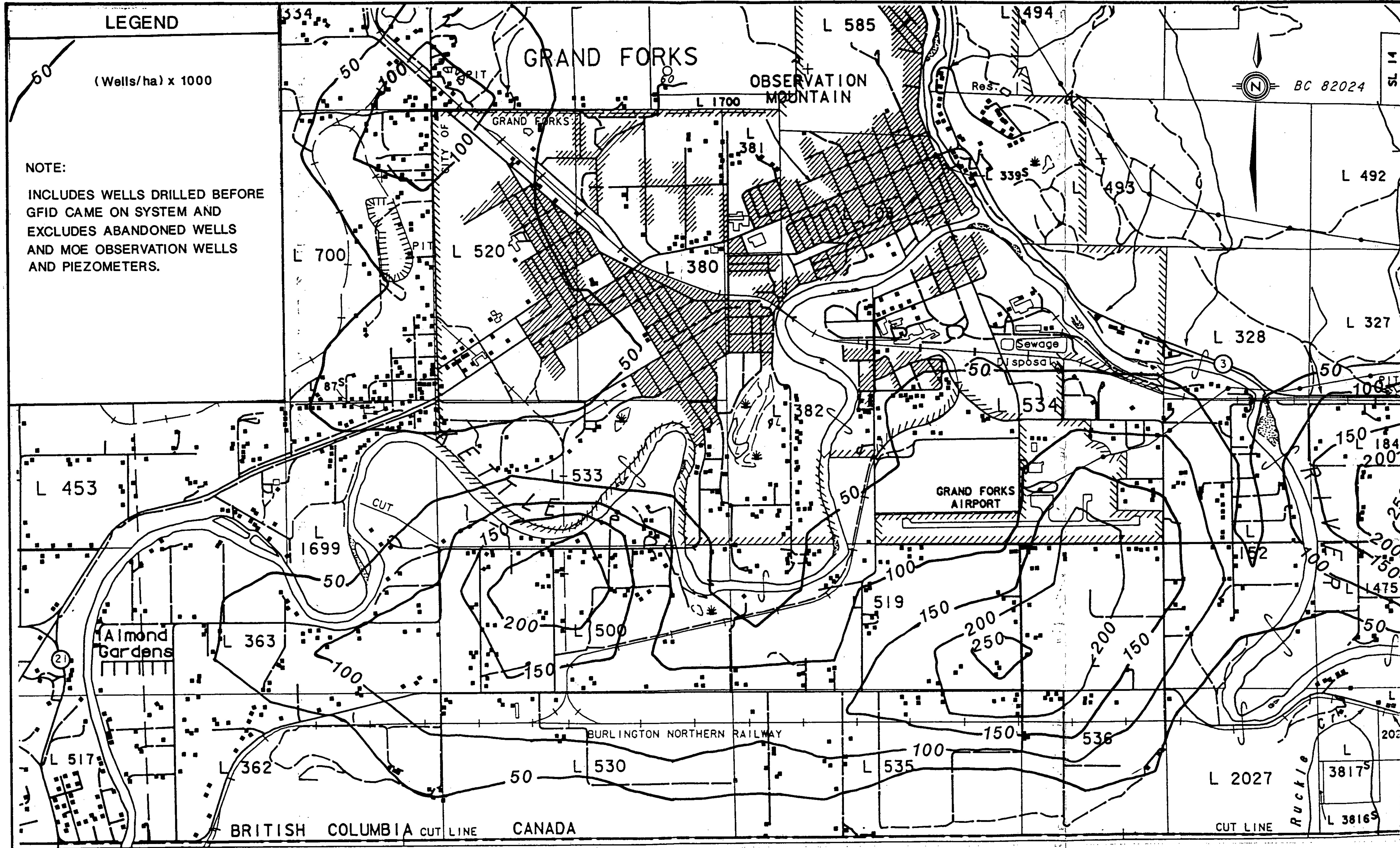
Samples from domestic wells for lab and field analyses were collected from running taps which were not connected up to any home filters or water softeners. The taps were allowed to run for a few minutes before sample collection. Samples from the piezometers were collected by bailing. A 1.5″ (40 mm) diameter, 30″ (0.7 m)-long stainless steel bailer was used. Prior to sample collection, the piezometers were bailed 80-100 times with the bailer to purge the piezometers of any stagnant water.

Sample Preparation

The samples for general ion and metals analysis were split. One-half of the sample was filtered through a 0.45 µm filter and the other half was left unfiltered. Samples for general ion analysis only were left unfiltered. Water samples containing fines were first filtered through a paper pre-filter to remove the fines. All samples were bottled in high density polyethylene bottles, packed in coolers, and shipped within 24 hours by courier to Zenon Environmental Inc., in Burnaby.

Preliminary Land-Use Survey

A preliminary land-use survey was conducted in October, 1991 for correlating existing land-use with NO_3 contamination in the aquifer. The survey involved a half-day tour of the area mapping general land-use on air photos. Detailed land-use for each property in the study area was not determined.



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GRAND FORKS AREA
WATER WELL DENSITY CONTOUR MAP APRIL 1988

SCALE: 1:20000		DATE MARCH 1992
M.WEI		ENGINEER
FILE No. 0329563-A	DWG No. FIGURE 12	

Results and Discussion

Results of the Initial Reconnaissance Survey

Field results of NO_3-N, specific conductance, hardness, Cl, and total alkalinity from the May, 1989 survey have been contoured and are shown in Figures 13-17. The contoured results reveal the areal distribution of those parameters in the study area.

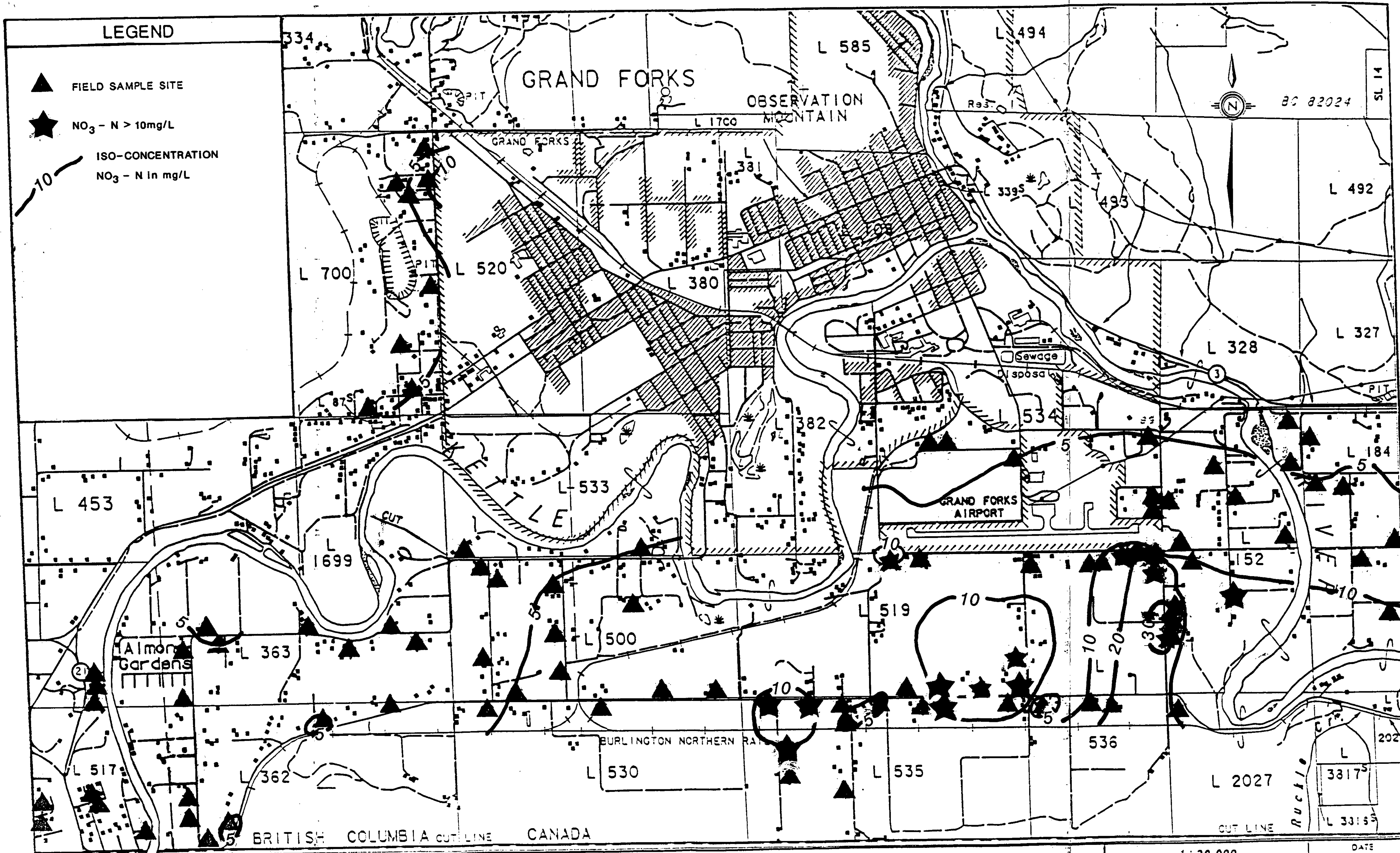
Areal extent of NO3-N distribution. Three major areas of NO_3-rich groundwater exist (Figure 13):

1) in the GFID south of the airport,
2) in the Nursery area of the GFID (east of the airport and Kettle River), and
3) along North Fork Rd. west of the City of Grand Forks (north of the Kettle River).

Within the GFID, NO_3-N concentration generally increases from west to east, reaching values of >30 mg/L NO_3-N along Kenmore Road directly south of the airport. The broad extent of the NO_3-N contours suggests a non-point source of nitrogen (Spalding et al, 1978). Nitrate concentrations in the City of Grand Forks, SID, and CID have not been sufficiently delineated from this survey because of lack of data points in those areas. The contour maps (Figures 13-17) represent conditions over the depth range of the wells sampled.

Well depths and NO_3-N Contamination. Field NO_3-N results plotted against well depths recorded from the survey show that NO_3-N, if present, decreases with increasing well depth (Figure 18). This general pattern suggests that NO_3-N is derived from surface sources. High NO_3-N (>10 mg/L) is found in well less than 100′ (30 m) deep. However, NO_3-N is not present in all shallow wells. The few deep wells (>100′) sampled during the reconnaissance survey have low NO_3-N values (<5 mg/L). A plot of NO_3-N against saturated depth was not possible because water levels and well construction details were not available for all wells during the survey.

NO3-N statistics. Approximately 23% of the wells sampled in May, 1989 showed NO_3-N concentration above the drinking water limit of 10 mg/L (refer to histogram in Figure 19). Sixty-six percent of the samples contain elevated levels of NO_3-N (>5 mg/L). The shape of the histogram suggests that the areal occurrence of NO_3-N in groundwater is log-normally distributed (Figure 20). The "average" NO_3-N concentration, based on the geometric mean for log-normal distribution (Domenico and Schwartz, 1990), is 5.4 mg/L (Table 2). This value may be slightly high because NO_3-N levels below 1 mg/L can not be accurately measured with the field kit. The arithmetic mean value of 7.1 mg/L is not an appropriate measure of the central tendency of areal NO_3-N distribution and overestimates the average NO_3-N



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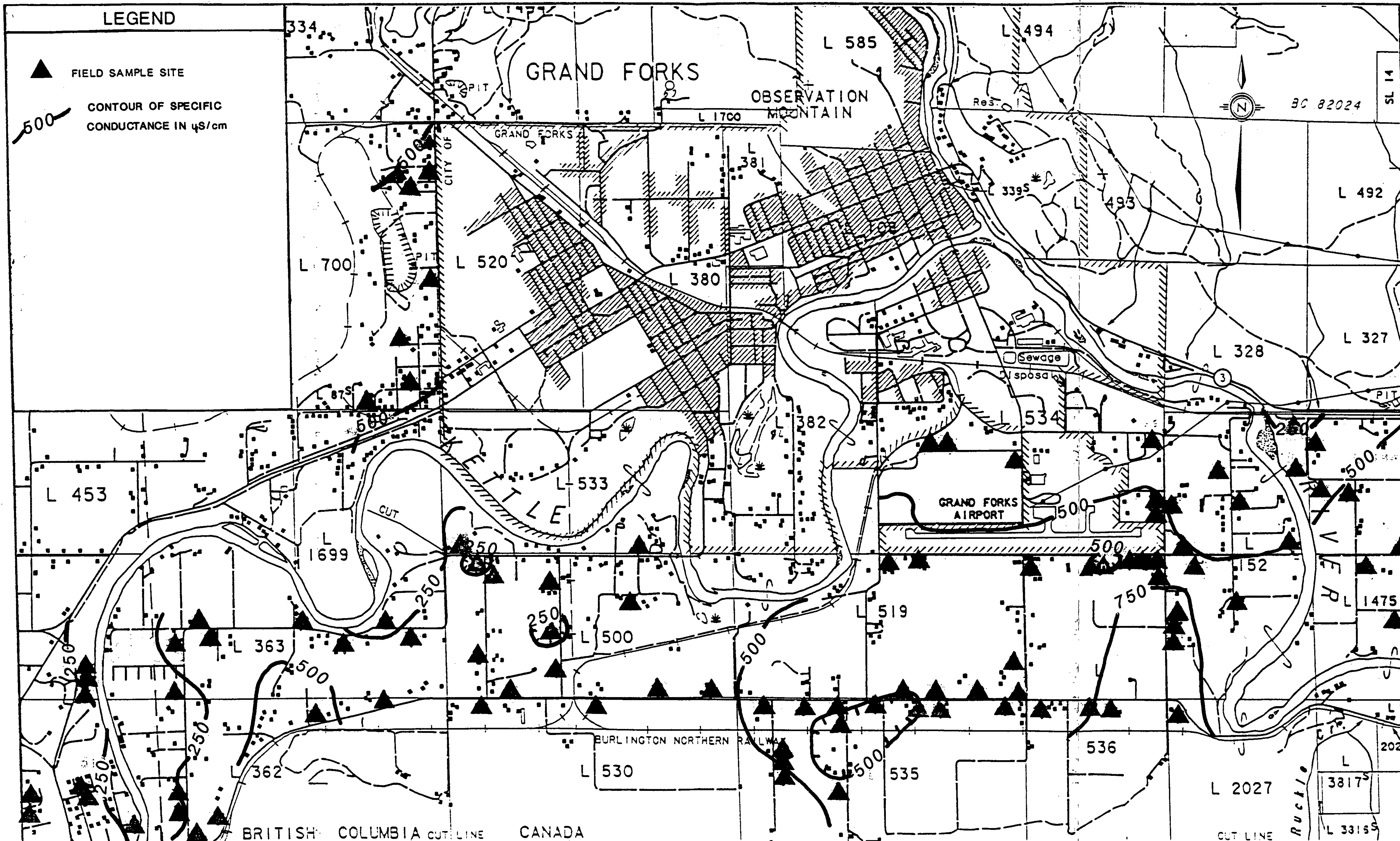
GROUNDWATER SECTION

GRAND FORKS AREA
OCCURRENCE OF NITRATE - NITROGEN (NO_3 - N) IN WELLS
BASED ON FIELD ANALYSES, MAY 1989

SCALE: 1 : 20 000
DATE: APRIL 1992
M. WEI ENGINEER
FILE No. 0329563-A DWG No. FIGURE 13



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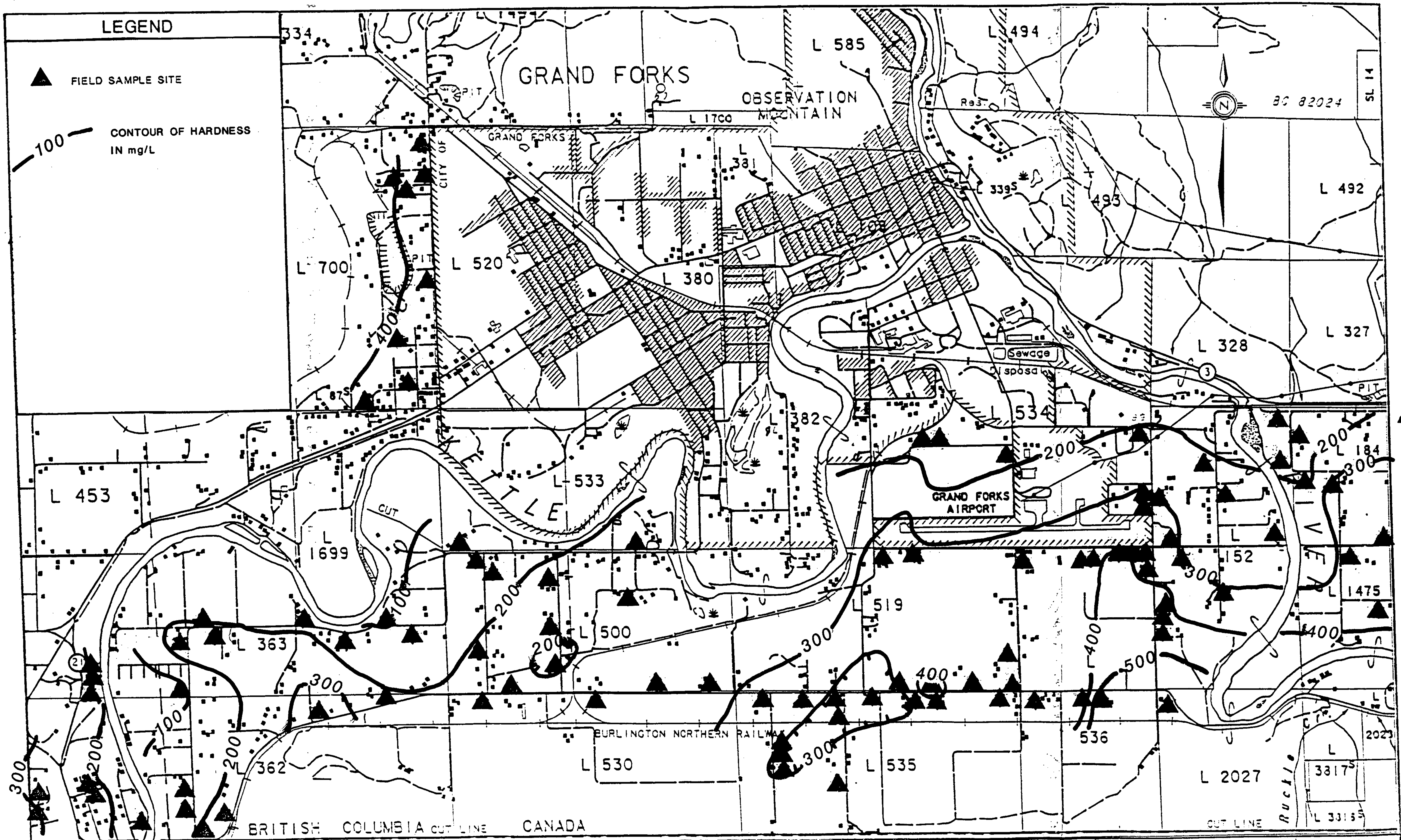
GRAND FORKS AREA
SPECIFIC CONDUCTANCE OF GROUNDWATER
BASED ON FIELD ANALYSES, MAY 1989

SCALE: 1 : 20 000	DATE APRIL 1992
M. WEI	ENGINEER
FILE No. 0329563-A	DWG No. FIGURE 14



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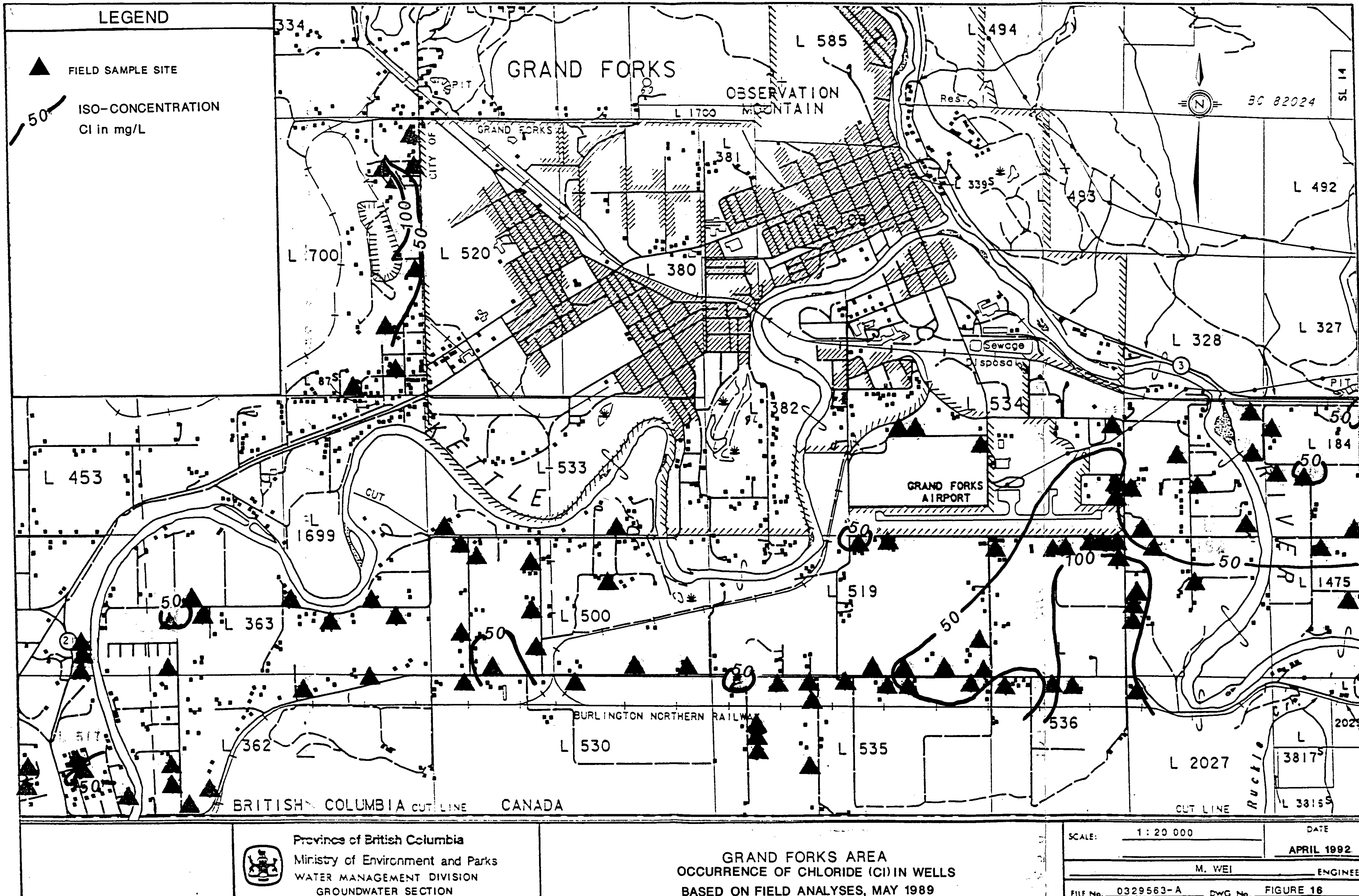
GROUNDWATER SECTION

GRAND FORKS AREA
HARDNESS OF GROUNDWATER
BASED ON FIELD ANALYSES, MAY 1989

SCALE: 1 : 20 000	DATE APRIL 1992
M. WEI	ENGINEER
FILE No. 0329563-A	DWG No. FIGURE 15


LEGEND
FIELD SAMPLE SITE
ISO-CONCENTRATION
Cl in mg/L
GRAND FORKS
OBSERVATION MOUNTAIN
GRAND FORKS AIRPORT
Sewage Disposal
KETTLE RIVER
BURLINGTON NORTHERN RAILWAY
BRITISH COLUMBIA CUT LINE CANADA
CUT LINE
BC 82024
L 585
L 494
L 492
L 327
L 328
L 184
L 1475
L 2027
L 700
L 520
L 380
L 381
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L 1699
L 363
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Province of British Columbia
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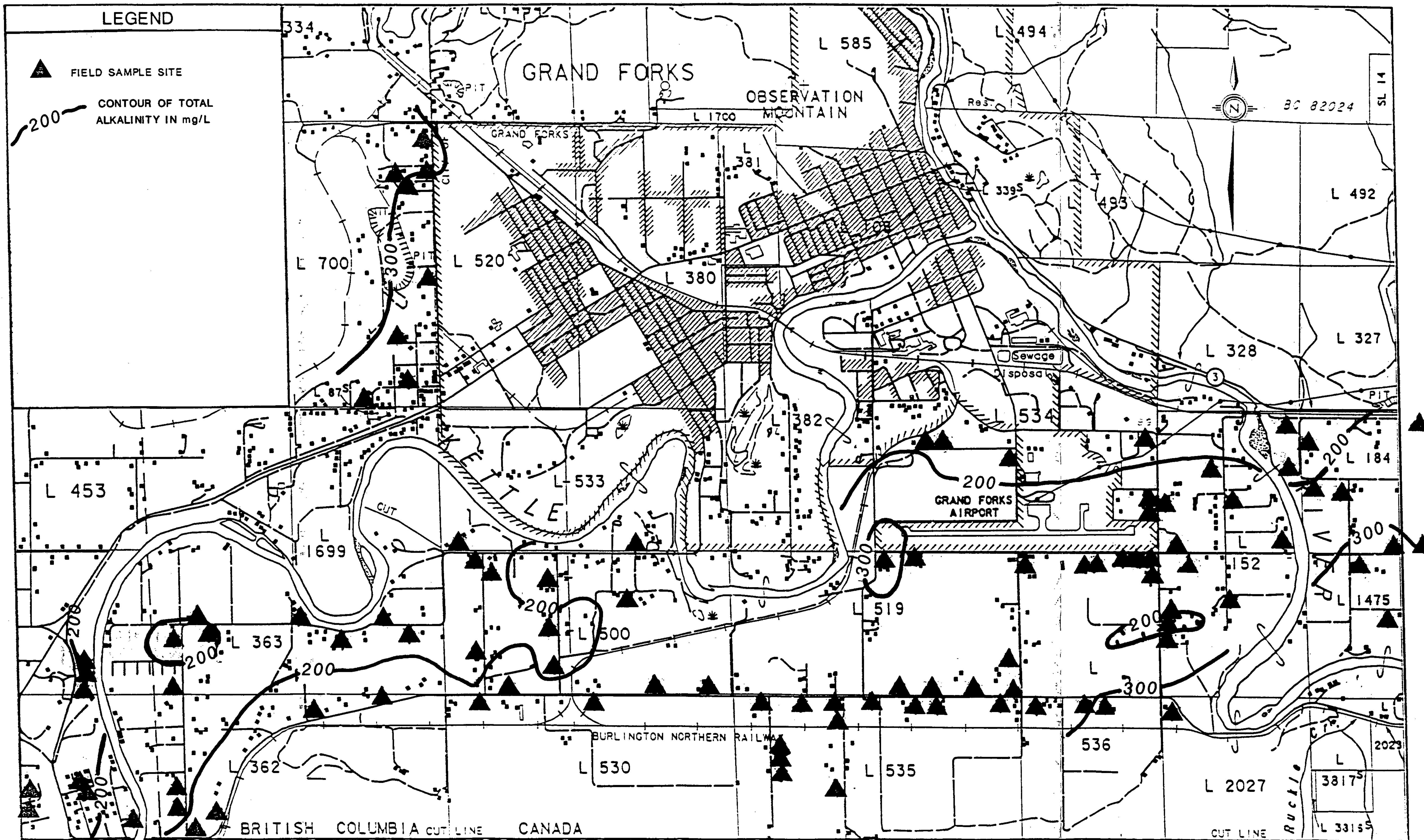
WATER MANAGEMENT DIVISION
GROUNDWATER SECTION
GRAND FORKS AREA
OCCURRENCE OF CHLORIDE (Cl) IN WELLS
BASED ON FIELD ANALYSES, MAY 1989
SCALE: 1:20 000
DATE
APRIL 1992
M. WEI
ENGINEER
FILE No. 0329563-A
DWG No. FIGURE 16



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Ministry of Environment and Parks
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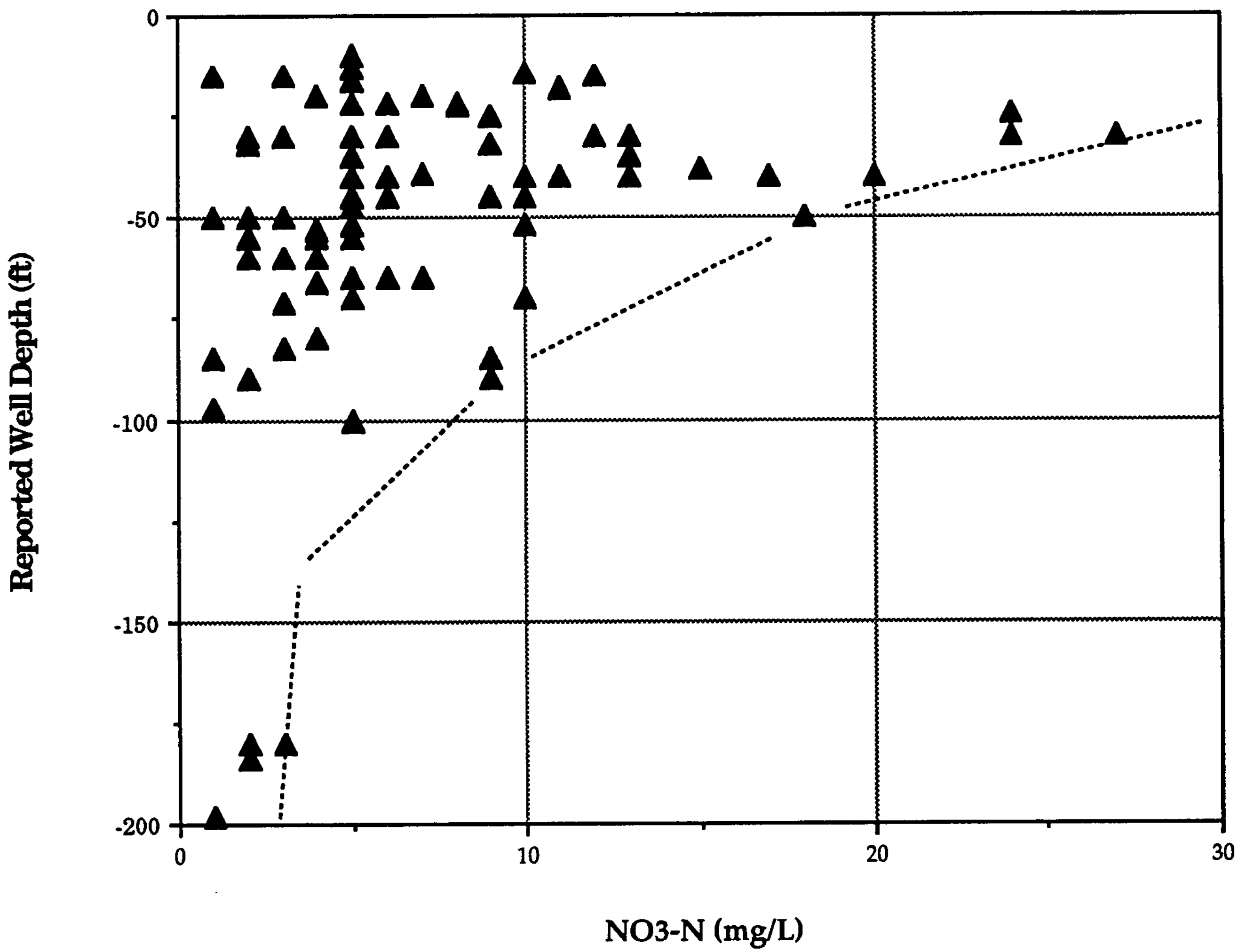
GROUNDWATER SECTION

GRAND FORKS AREA
TOTAL ALKALINITY OF GROUNDWATER
BASED ON FIELD ANALYSES, MAY 1989

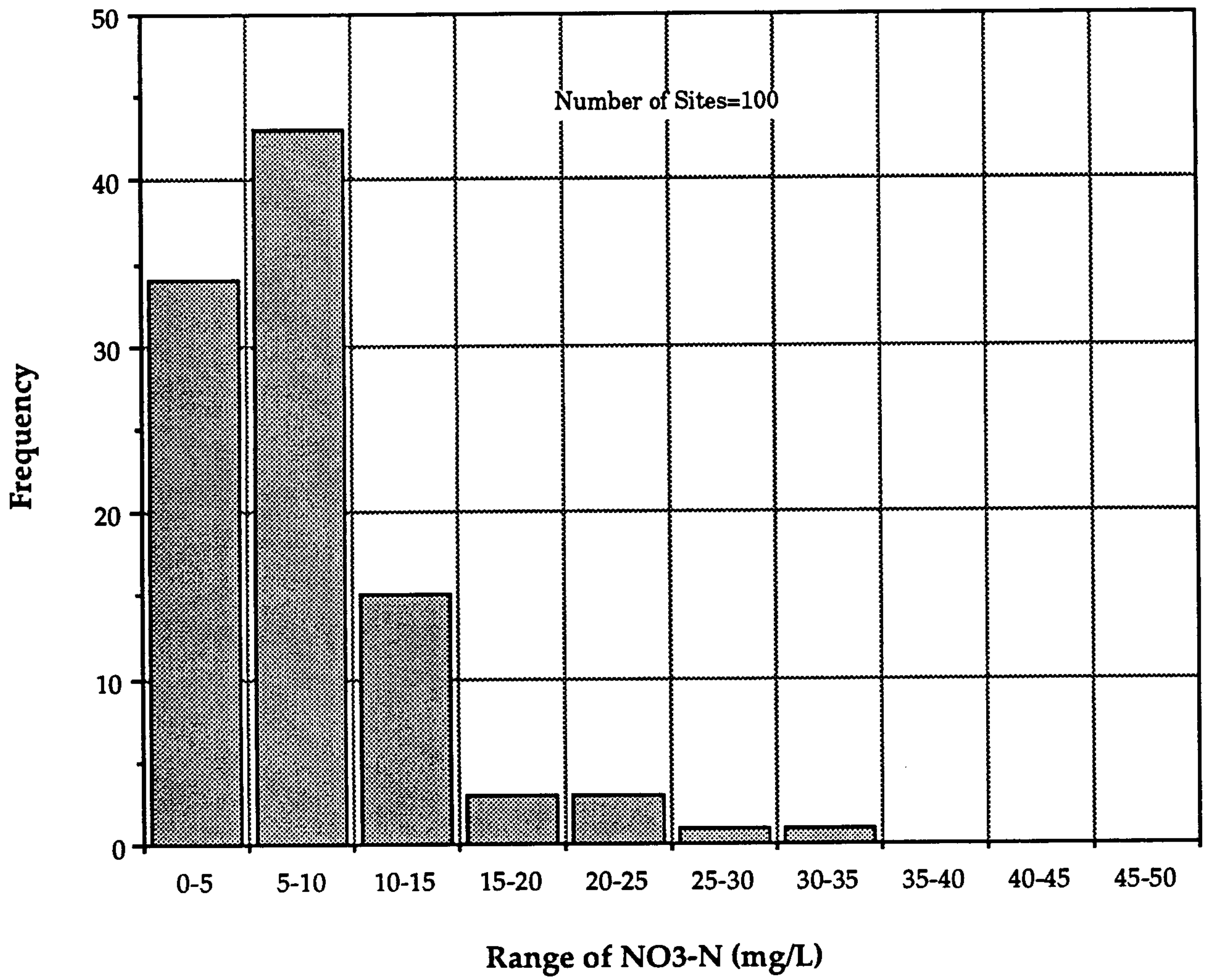
SCALE: 1 : 20 000
DATE: APRIL 1992
M. WEI ENGINEER
FILE No. 0329563-A DWG No. FIGURE 17

Figure 18. NO3-N as a Function of Reported Well Depth



Based on 1989 field survey (Kalyn, 1989)

Figure 19. Histogram of NO3-N Occurrence in Groundwater, Grand Forks



Based on 1989 field survey (Kalyn, 1989)

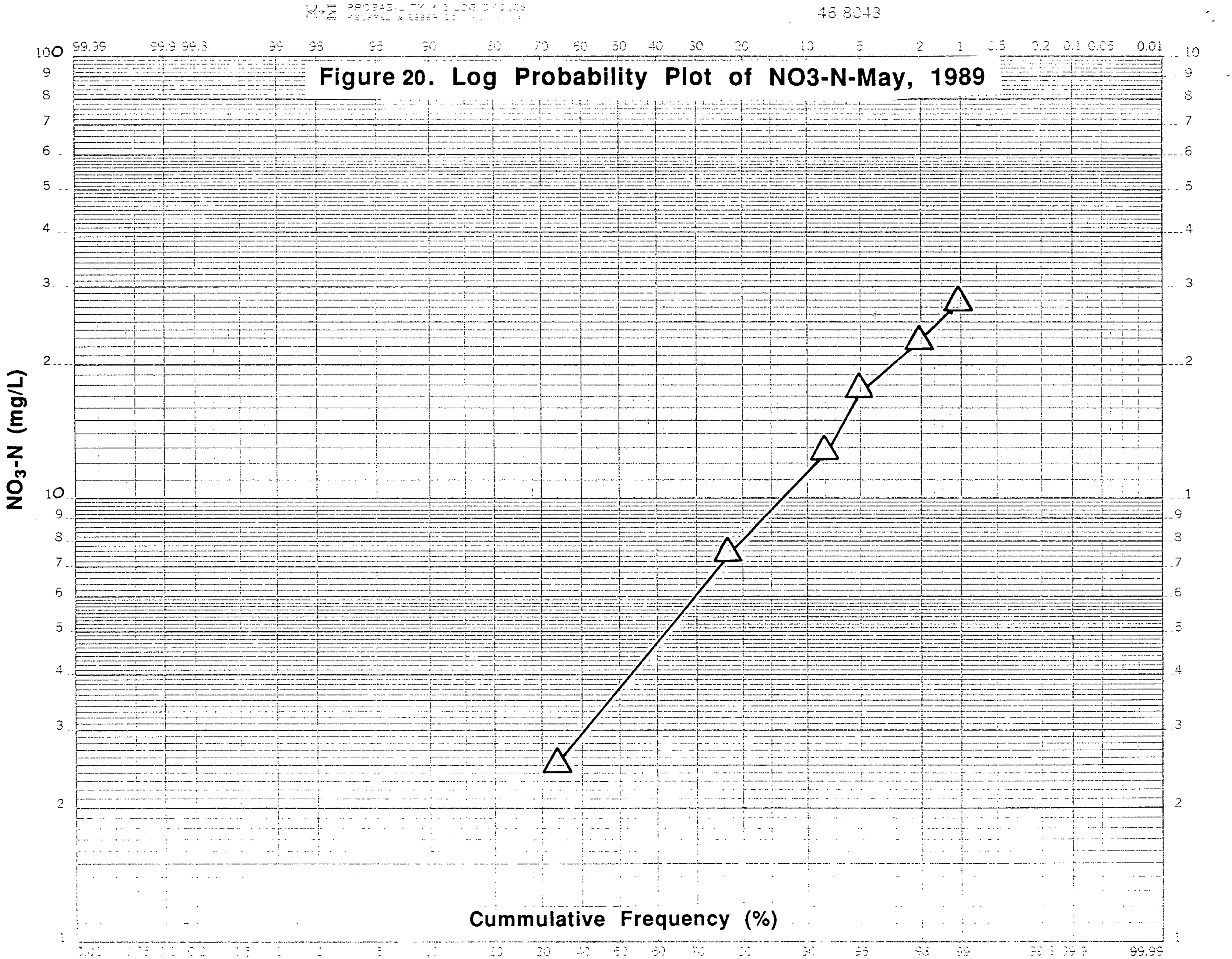


Figure 20. Log Probability Plot of NO3-N-May, 1989
NO3-N (mg/L)
Cummulative Frequency (%)
46 8043

concentration. The median value of 5.5 mg/L is close to the geometric mean.

Table 2. "Average" NO_3-N from Field Hach Results

Central Tendency	NO_3-N (mg/L)
Geometric Mean	5.4
Arithmetic Mean	7.1
Median	5.5

NO_3-N association with other field parameters. Occurrence of high NO_3-N are associated with areas of high specific conductance, hardness, and Cl (Figures 13-17). Note the high values of these parameters south of the airport, in the Nursery area, and west of the City of Grand Forks where high NO_3-N also occurs. Specific conductance, hardness, and Cl also generally increase from west to east in the GFID. The area of lower NO_3-N along Carson Road, near Como Road, is also consistent with lower values of specific conductance and hardness. Areas of lower specific conductance and hardness occur adjacent the Kettle River where the aquifer receives recharge locally from the river.

A correlation matrix for the 100 field results quantifies the association between the different field parameters (Table 3). The number in the table is the correlation coefficient, r, which ranges between -1 and 1. A positive r-value means the parameters are directly correlated. A negative r-value means the parameters are inversely correlated. The closer the r-value is to 1 or -1 (r^2=1), the stronger the correlation.

Table 3. Correlation Coefficients (r) for Field Parameters

Parameter	NO_3-N	Spec Cond	Hardness	pH	Tot Alk	Cl	Fe
NO_3-N	-	0.73	0.68	0.13	0.20	0.70	-0.18
Spec Cond		-	0.94	-0.11	0.66	0.76	-0.30
Hardness			-	-0.08	0.74	0.70	-0.28
pH				-	-0.17	-0.134	0.06
Tot Alk					-	0.31	-0.36
Cl						-	-0.12
Fe							-

Nitrate-nitrogen, specific conductance, hardness (calcium and magnesium), and Cl are correlated with each other (r > 0.7) as consistent with Figures 13-17. Total alkalinity correlates with specific conductance and hardness but does not appear to be associated with NO_3-N (Figures 13-17). pH and iron do not appear related to NO_3-N concentrations.

Although alkalinity generally increases from west to east in the GFID, similar to the pattern of NO_3-N distribution, higher values are not evident south of the airport where high NO_3-N occurs. In fact, the alkalinity contour actually shows a depression south of the airport where high NO_3-N values occur (Figure 17). Total alkalinity is relatively low compared to hardness and specific conductance in high NO_3-N areas (Appendix B). The increase in alkalinity towards the east probably reflects natural chemical evolution of the groundwater as it flows downgradient.

Correlation between lab and field results. The field results of the domestic wells correlate with results from the lab (Appendix C). Lab results are assumed to be more accurate. Field NO_3-N values, in general, are lower than lab NO_3-N values (Table 4). The NO_3-N values in the 3 major contamination areas in Figure 17 may, therefore, be conservative; actual NO_3-N values in those areas may be higher. Based on the correlation between field and lab results, field results can be used to delineate the distribution of NO_3-N and specific conductance.

Field alkalinity and Cl values are generally higher than their corresponding lab values. Alkalinity and chloride values are determined in the field by titration which is inaccurate for low concentrations (<20 mg/L). Field results for Cl and alkalinity do, however, show the general patterns of distribution. Lack of correlation for pH may be due to the lack of resolution of the field Hach instrument and/or the change in pH of the samples from field to laboratory conditions due to changes in temperature and pressure.

Table 4. Correlation between Field and Lab Results

Parameter	r	Comments
NO_3-N	0.93	field < lab above 5 mg/L
Spec Cond	0.98	field < lab by ~10%
pH	0.58	field > lab
Tot Alk	0.86	field > lab by ~30%
Cl	0.97	field > lab

Lab Results from Initial Sampling of the 14 Domestic Wells

Lab results of the 14 domestic wells are generally consistent with the field results (Figures 21 to 28). Nitrate-nitrogen is:

- highly correlated with specific conductance, TDS, Cl, and SO_4 ($r > 0.7$) and
- moderately correlated with Na, K, N_{org}, and F (Table 5).

Nitrogen from inorganic fertilizers. The high to moderate correlation of NO_3-N with Cl, SO_4, K, F, and hardness (from the field results) suggests that NO_3-N is derived from inorganic fertilizers. Inorganic fertilizers typically contain:

Figure 21. Correlation of (NO2+NO3)-N with Specific Conductance-May, 1989

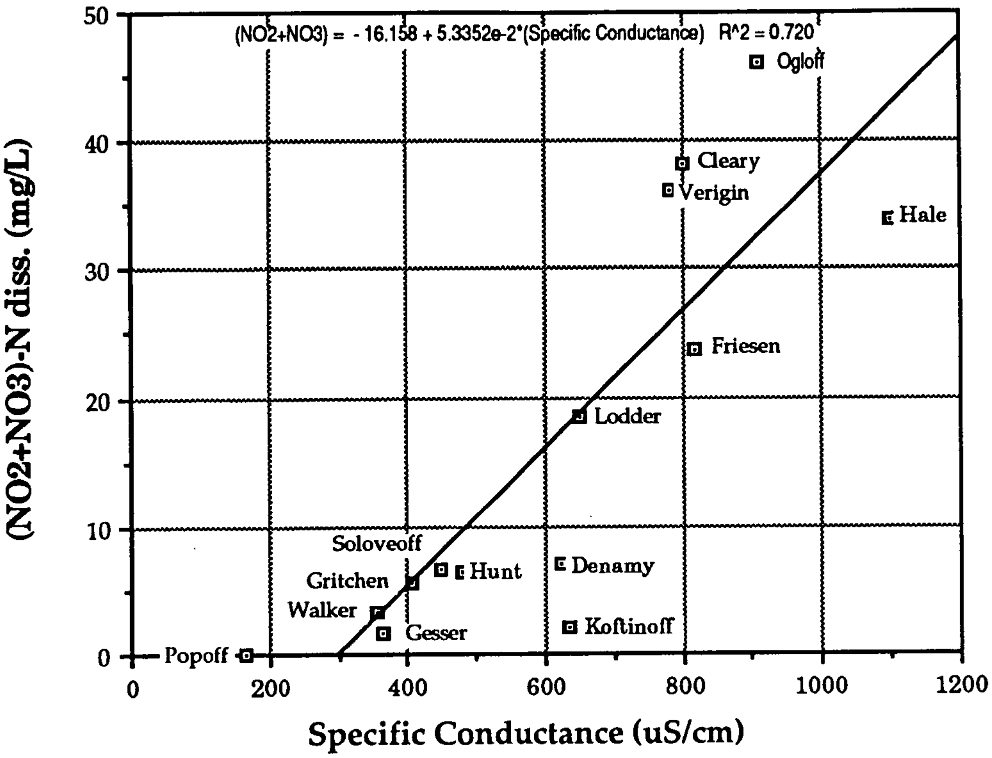


Figure 22. Correlation of (NO2+NO3)-N with Residue Filterable-May, 1989

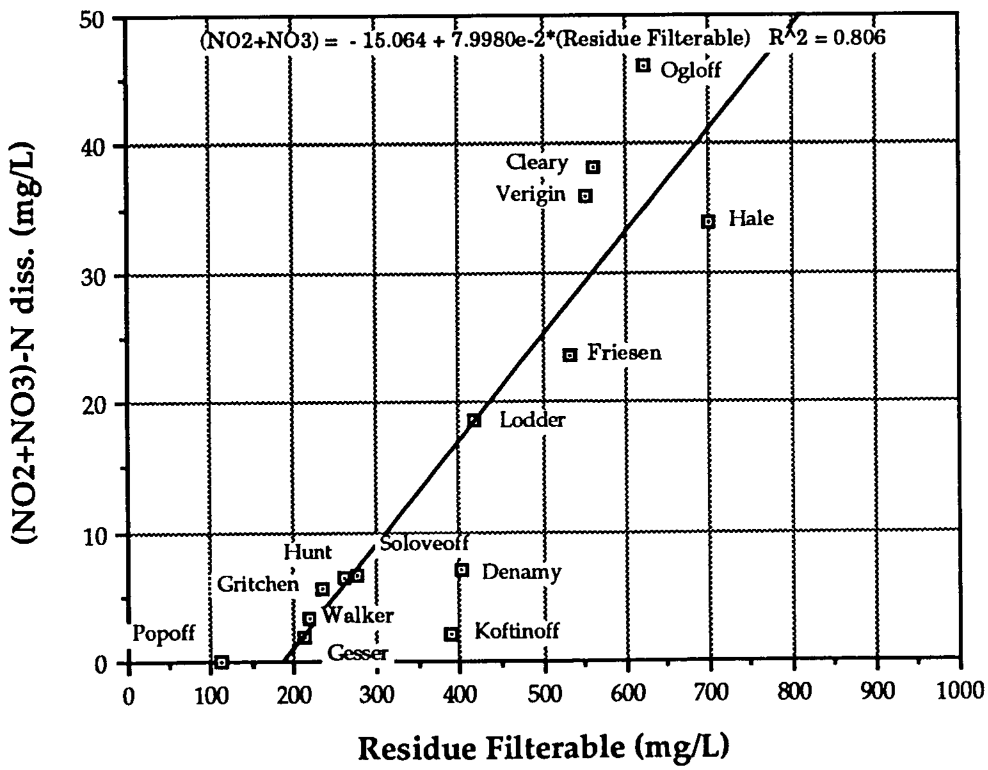


Figure 23. Correlation of (NO2+NO3)-N with Cl-May, 1989

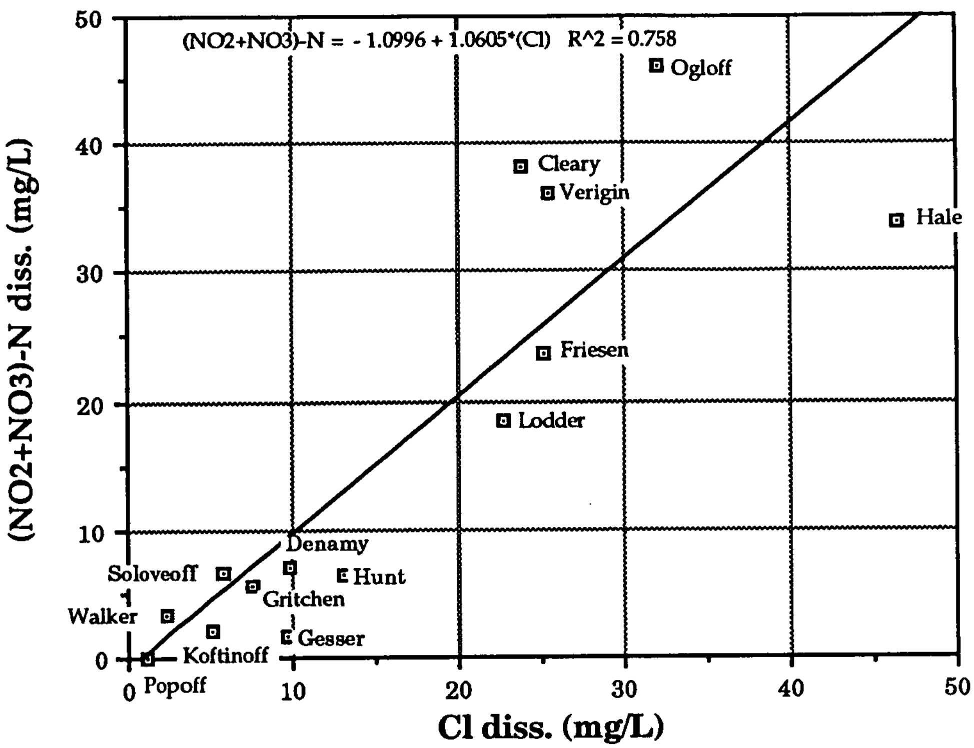


Figure 24. Correlation of (NO2+NO3)-N with SO4-May, 1989

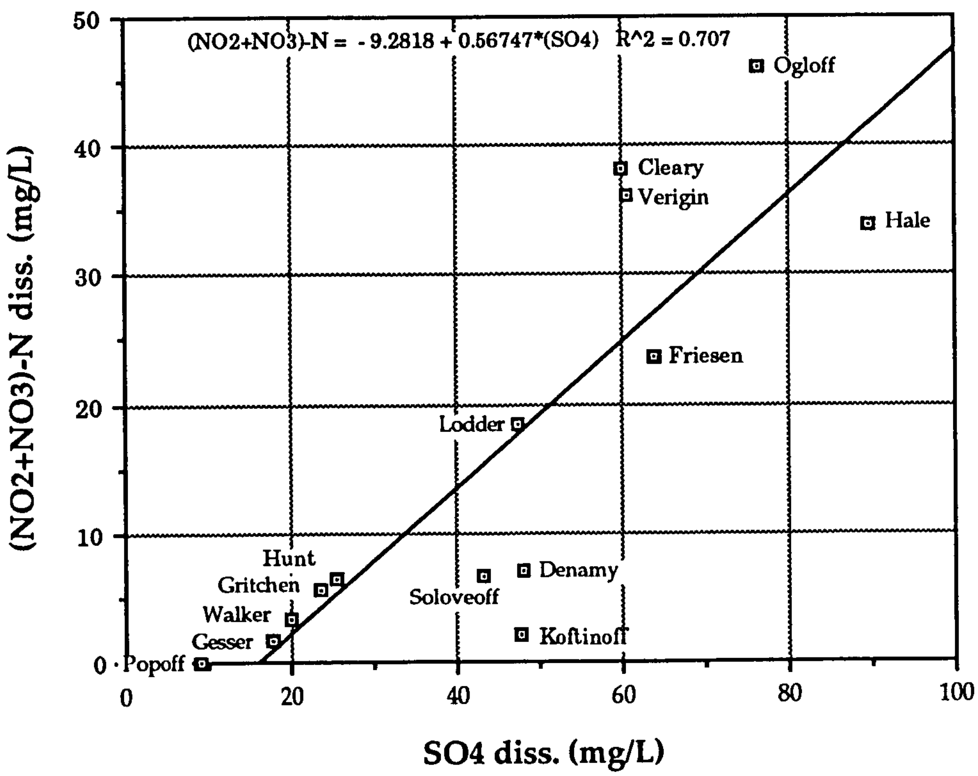


Figure 25. Correlation of (NO2+NO3)-N with Na-May, 1989

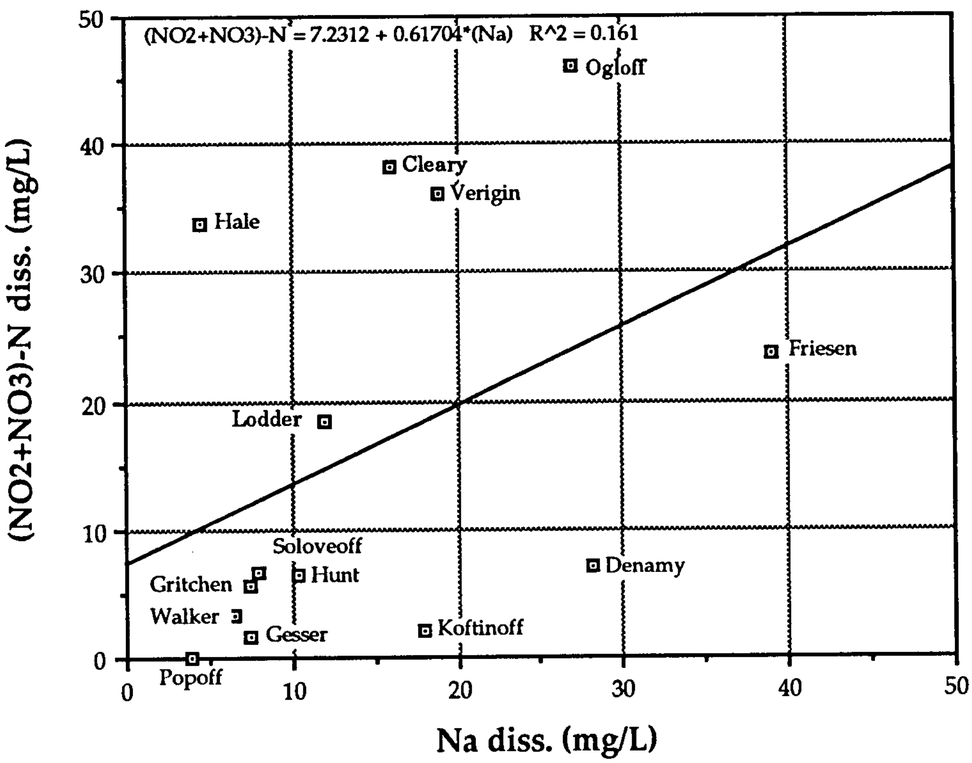


Figure 26. Correlation of (NO2+NO3)-N with K-May, 1989

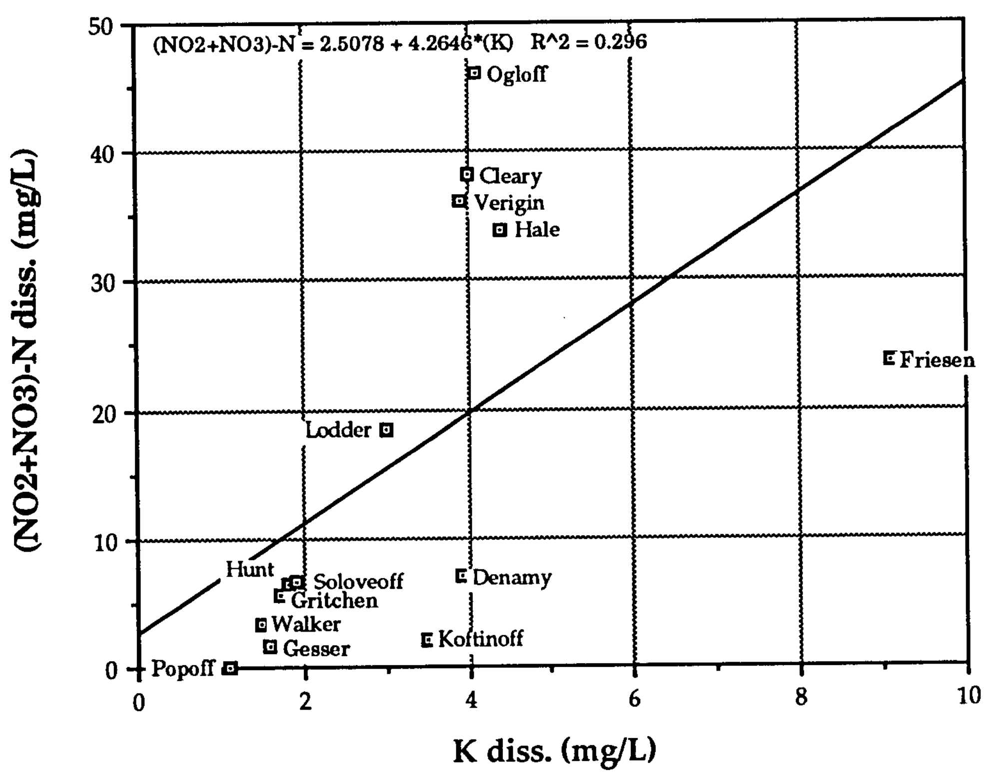


Figure 27. Correlation of (NO2+NO3)-N with N org.-May, 1989

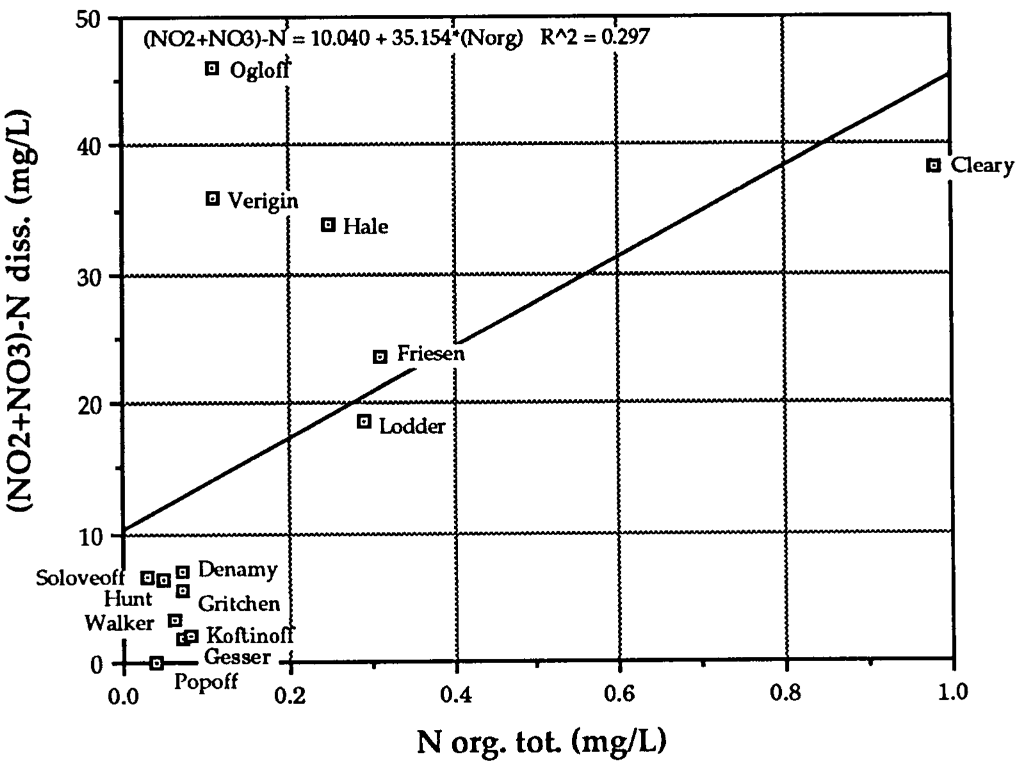


Figure 28. Correlation of (NO2+NO3)-N with F-May, 1989

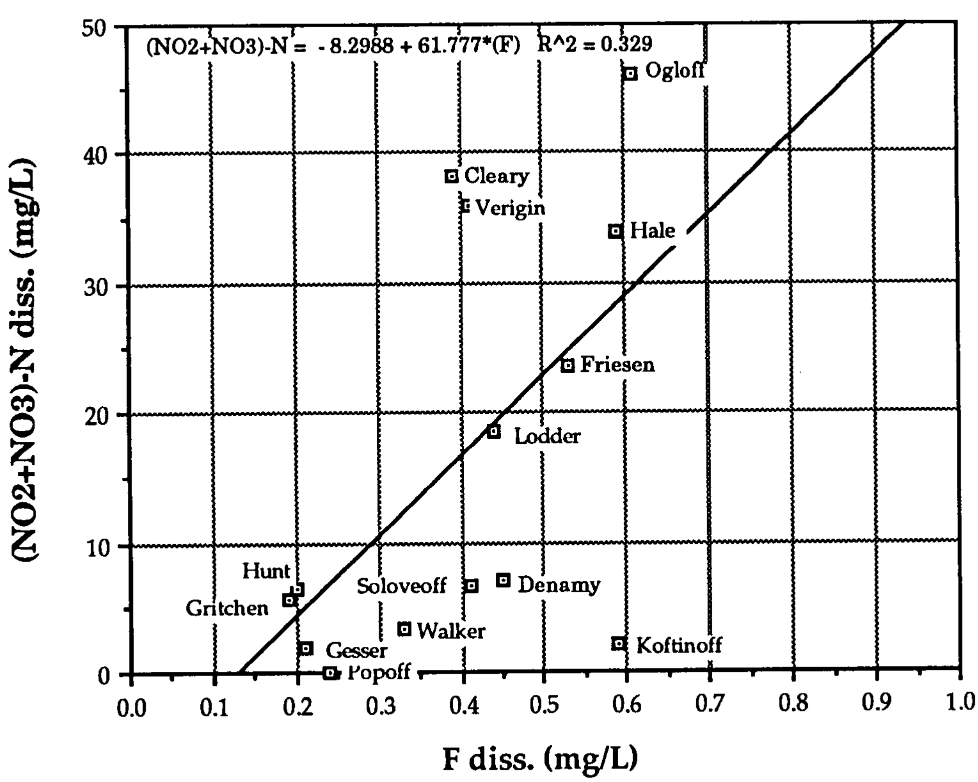


Table 5. Correlation table for the 15 Domestic Lab Results

	NO_3-N	Spec Cond	TDS	Na	K	P	N_{org}	Cl	HCO_3	F	SO_4
NO_3-N	-	0.85	0.90	0.40	0.54	0.20	0.55	0.87	0.18	0.57	0.84
Spec Cond		-	0.99	0.48	0.71	0.40	0.44	0.92	0.67	0.79	0.98
TDS			-	0.51	0.71	0.38	0.48	0.91	0.59	0.79	0.98
Na				-	0.83	0.60	0.18	0.27	0.39	0.55	0.48
K					-	0.87	0.37	0.58	0.59	0.66	0.70
P						-	0.16	0.36	0.49	0.37	0.39
N_{org}							-	0.41	0.09	0.18	0.39
Cl								-	0.46	0.59	0.88
HCO_3									-	0.69	0.64
F										-	0.86
SO_4											-

anhydrous ammonia (NH_3),
ammonium nitrate (NH_4NO_3),
ammonium sulfate ($(NH_4)_2SO_4$),
diammonium phosphate ($(NH_4)_2HPO_4$),
monoammonium phosphate ($NH_4H_2PO_4$),
calcium phosphate ($Ca(H_2PO_4)_2$),
calcium sulfate ($CaSO_4$),
magnesium sulfate ($MgSO_4$),
and potassium chloride (KCl)

for example (Peterson and Frye, 1989; Vrba and Romijn, 1986; Brown and Lemay, 1977). These components dissociate into ionic form in water. Ammonium is converted into NO_3 by nitrification. Nitrate, Cl, and SO_4 are mobile but phosphate, Ca, Mg, and K are affected by ion exchange with clays in the soil (Drever, 1988; Freeze and Cherry, 1979). Calcium and Mg may also be derived from lime applied to the soil. Ion exchange may explain why NO_3-N is onl;y weakly correlated with K (Figure 26). Fluoride may be from dissociation of fluoroapatite, a common addition in phosphate and superphosphate fertilizers (Vrba and Romijn, 1986).

Correlation of NO_3-N with specific conductance and TDS reflects general increase in ionic concentration of groundwater from fertilizer chemicals leaching into the aquifer (Figures 21 and 22).

The relatively low alkalinity in high NO_3-N areas may reflect a *common ion effect* (Drever, 1988; Freeze and Cherry, 1979). Elevated Ca (hardness) from $CaSO_4$ in fertilizers in high NO_3-N areas affects the equilibrium concentration of alkalinity (HCO_3) with respect to calcite resulting in lower alkalinity (and pH) values. The effect on pH can not be accurately determined on the basis of the field measurements of pH with the equipment utilized.

Nitrogen from septic systems. Nitrate from septic sources does not appear to be a major contributer to NO_3-N in the aquifer. Rural residential areas which are on septic systems (eg. Almond Gardens area, north of the Danville border crossing, and near Highway No. 3 and North Fork Rd.) are not where the highest nitrate levels occur. Density of rural homes in the study area is also low.

Anomalous results. The Denamy and Koftinoff wells do not follow the correlation trends. Nitrate-nitrogen values for those wells are generally lower (for example, Figures 21 and 22). The Koftinoff well apears to be tapping more mineralized groundwater that is not directly associated with high NO_3-N. Groundwater in the SID and North Fork Rd. areas is generally more mineralized than groundwater in the GFID area. The results from the Denamy well can not be as yet be explained.

Inconsistencies between field and lab results exist for the Koftinoff well. Although field analysis of Koftinoff's well showed a value of 10 mg/L for NO_3-N, the lab result was lower (2.1 mg/L NO_3-N). This may be due to field measurement errors.

The low level of NO_3-N and other chemical parameters for the Popoff well indicates that well is tapping water derived from infiltration from the Kettle River (for example, Figures 21 and 22).

The Friesen well contains relatively high K, Na, and P values (Figures 25 and 26). Potassium and P are correlated with each other ($r^2 = 0.87$) suggesting that they originate from the same source (Table 5). Potassium and phosphate are normally susceptible to ion exchange with clays in the soil but the relatively high K, P, and Na values suggest the source is very close to the well. An inspection of the local land use around the well head may help explain the anomalous results.

Except for the Cleary well, NO_3-N appears to occur independently of organic nitrogen (N_{org}). This appears to support the hypothesis that NO_3-N in groundwater is governed by inorganic sources. The N_{org} in Cleary's well appears to significantly influence the correlation (Figure 27).

Initial Piezometer Results

Results of the May, 1990 first ever sampling round of the piezometers are consistent with the results of the reconnaissance survey and indicate that the NO_3-N is derived from a surface source (Figure 29). Nitrate-nitrogen generally decreases with depth at all 3 sites. Nitrate-nitrogen concentrations at shallow depths (above 60′) are greatest at Site C and lowest at Site B. Concentrations at the 60-foot (18 m) depth at Site A and 40-foot (12 m) depth at Site C exceed the drinking water limit of 10 mg/L; concentrations at Site B are below the drinking water limit.

Concentrations as a Function of Depth. The decrease in NO_3-N concentration with depth may be due to either dispersion of NO_3-N at depth or denitrification. Dispersion at depth would not be a plausible explanation if nitrate transport is controlled mostly by advection in permeable deposits which is believed to be the case here. Similar trends with depth are observed at the Abbotsford piezometer sites where denitrification is occurring (Kohut et al, 1989 and Sather, 1989). Denitrification in shallow sandy aquifers have also been observed by Gillham and Cherry (1978). Measurements of ^{15}N isotope, denitrifying bacteria in the aquifer, dissolved organic carbon (DOC), and redox potential of the groundwater will clarify if denitrification is occurring at depth in the aquifer.

Profile plots for other chemical parameters also show a general decrease in concentrations with depth at Sites A and C (Figures 30 to 37). This is expected because NO_3-N correlates with many of these parameters such as specific conductance, TDS, hardness, Cl, SO_4, and K. Shallow depths at Site C consistently show the highest concentrations. One exception is the high SO_4 at 60-foot (18 m) at Site C which does not correlate with NO_3-N at that depth.

Figure 29. NO3-N Profile at Sites A, B, C-May, 1990

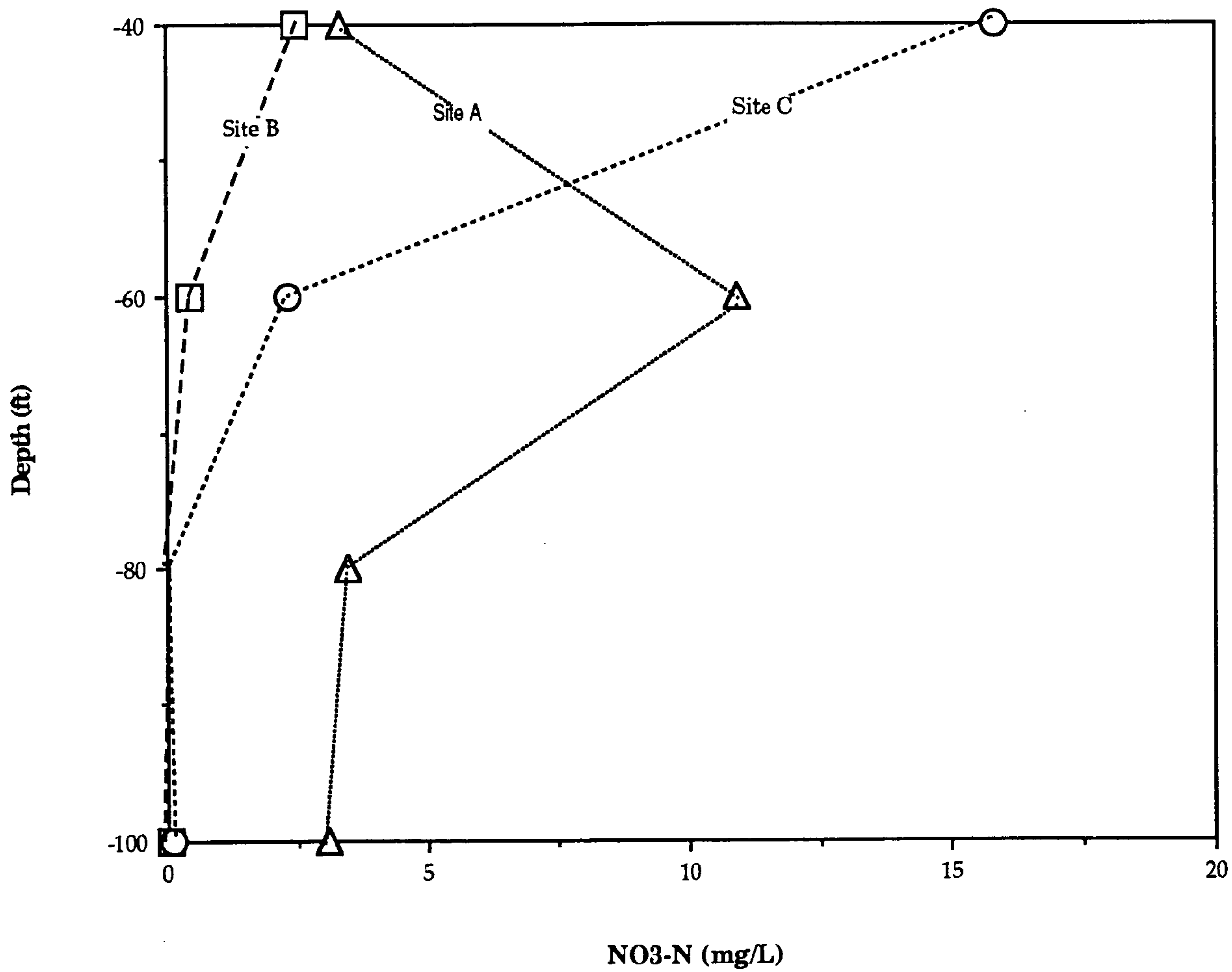


Figure 30. Profile of Specific Conductance at Sites A, B, C-May, 1990

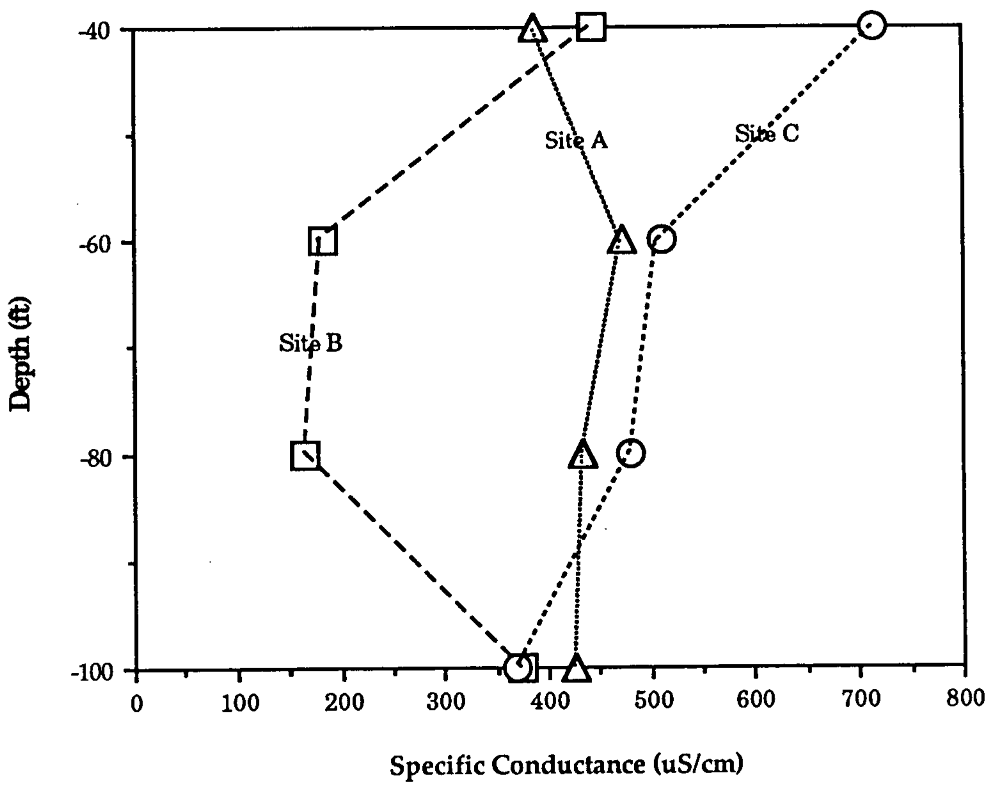


Figure 31. Profile of Residue Filterable at Sites A, B, C-May, 1990

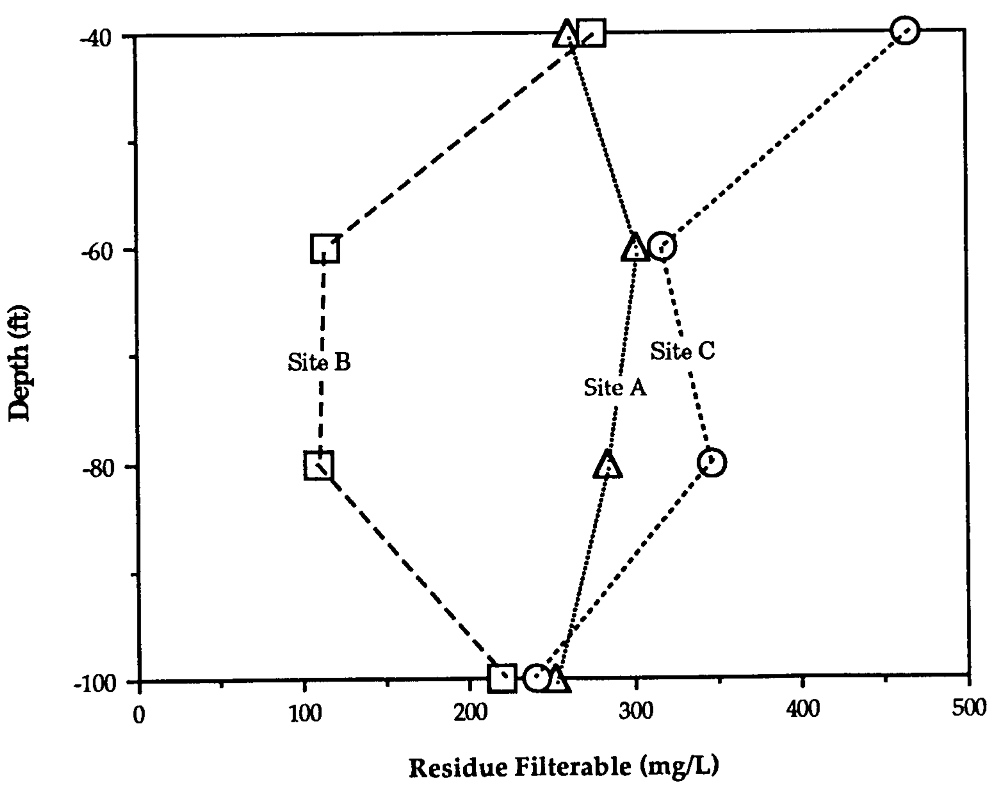


Figure 32. Profile of Hardness at Sites A, B, C-May, 1990

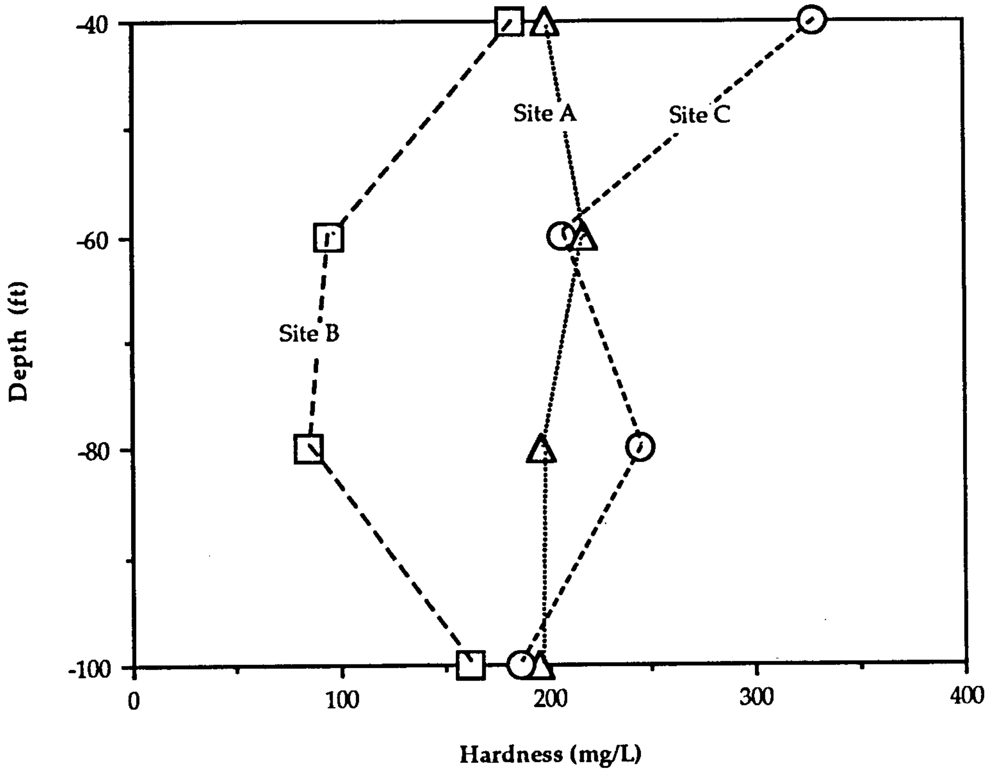


Figure 33. Profile of Cl at Sites A, B, C-May, 1990

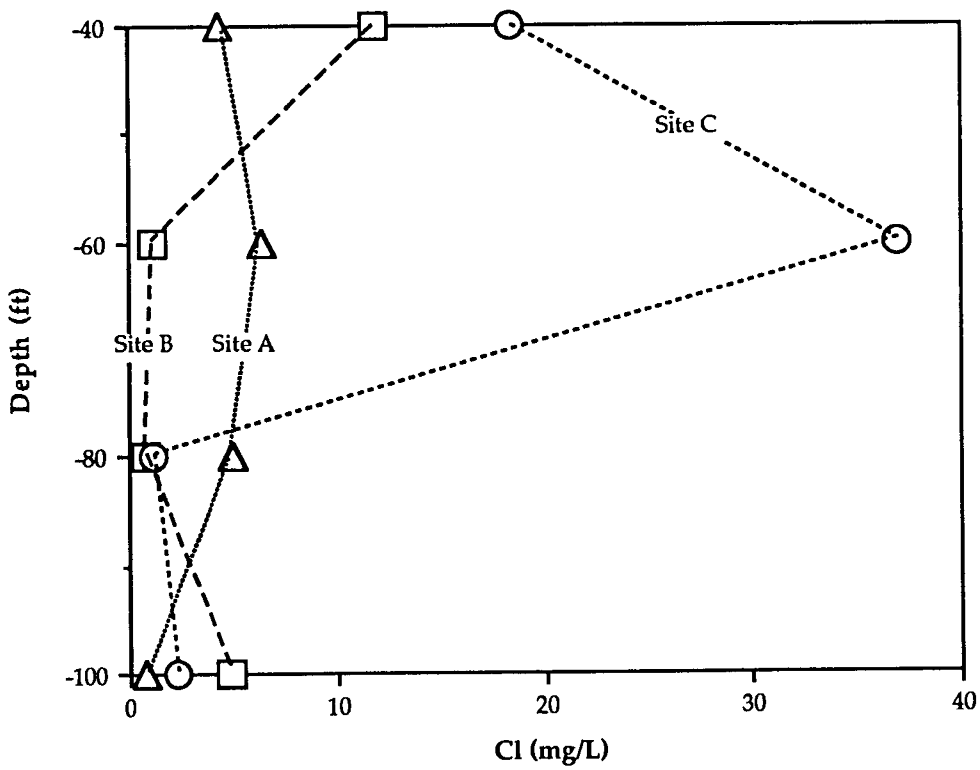


Figure 34. Profile of SO4 at Sites A, B, C-May, 1990

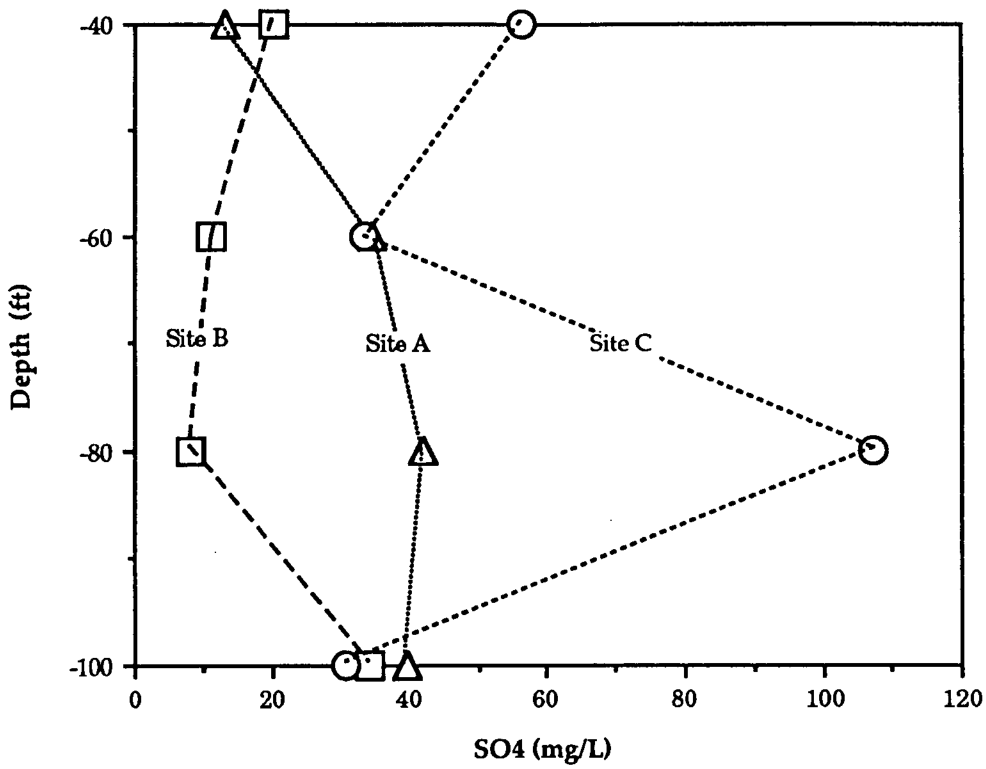


Figure 35. Profile of K at Sites A, B, C-May, 1990

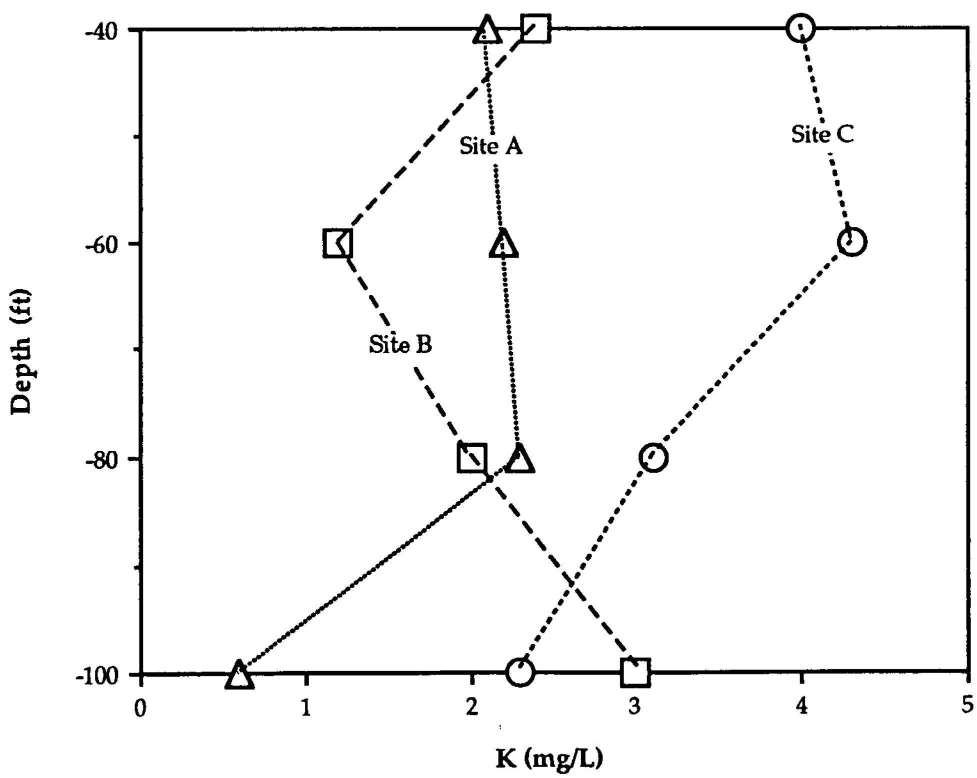


Figure 36. Profile of Na at Sites A, B, C-May, 1990

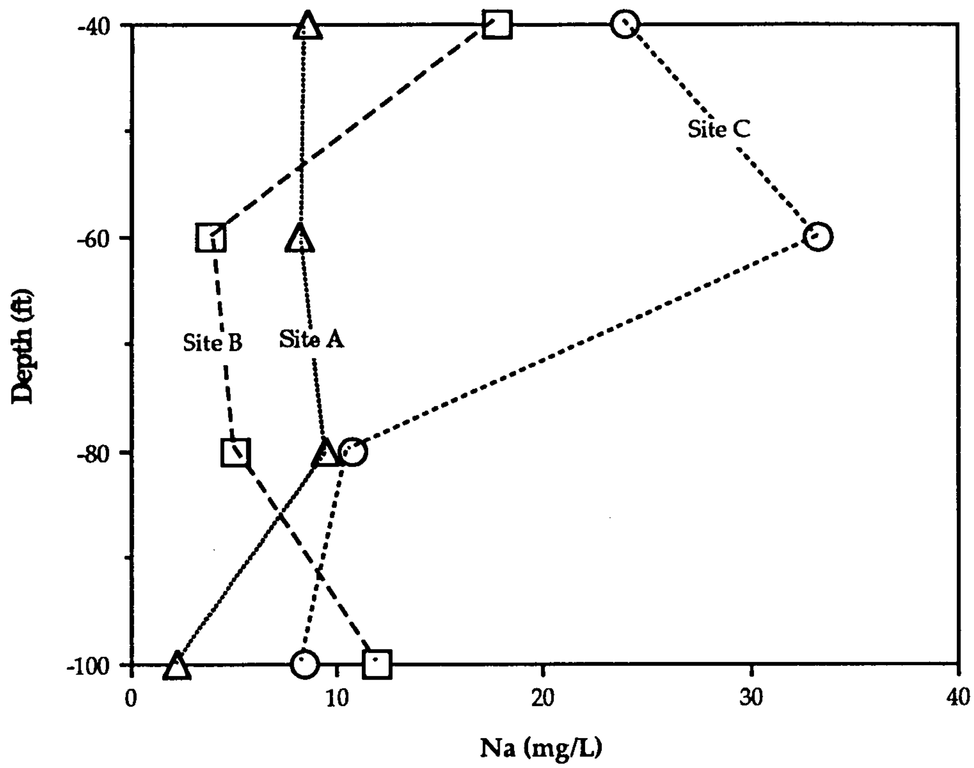
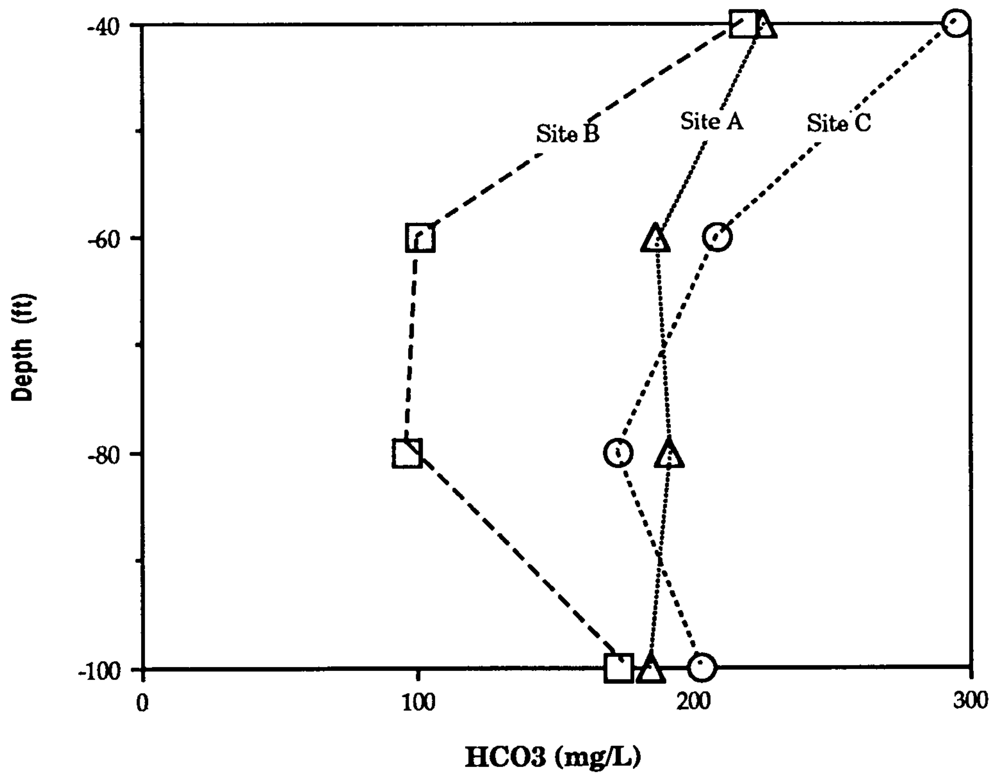


Figure 37. HCO3 Profile at Sites A, B, C-May, 1990



Recharge from the Kettle River. Profiles of chemical parameters at Site B reveal the hydraulic influence of the Kettle River near that site. Concentrations are generally lower than at Sites A and C (Figures 29 to 37). The relatively lower concentrations at 60′ (18 m) and 80′ (24 m) depths at Site B indicate that less mineralized water from the Kettle River is recharging locally into the aquifer. The lower values of specific conductance and hardness in the aquifer proximal to the Kettle River in Figures 14 and 15 also reflect this recharge.

Effect of recharge from the river is evident to a depth of between 80′ (24 m) and 100′ (30 m). The more mineralized water at the 40-foot (12 m) depth at Site B indicates that the upper surface of the aquifer is also receiving recharge from the vadose zone. At Site B, concentrations below 80′ (24 m) increase due to the presence of more mineralized groundwater at depth. The only chemical parameter that does not increase at 100′ (30 m) at Site B is NO_3-N suggesting that NO_3-N is not derived from the aquifer.

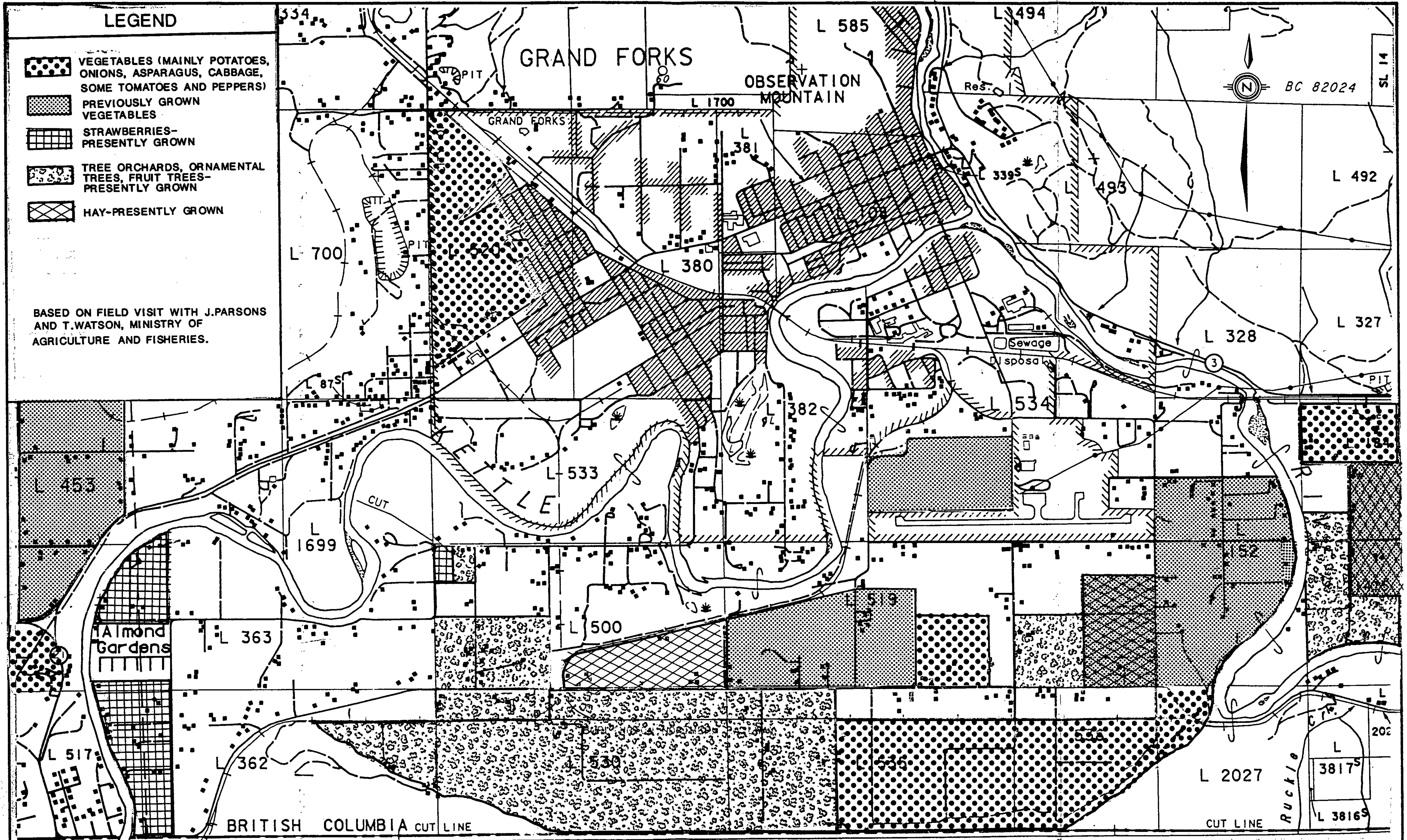
Correlation of NO_3-N Occurrence with Land-Use

Land use patterns are generally consistent with occurrence of NO_3-N in the study area (Figure 38). Historically, agricultural activity has been more intensive in the eastern portion of the GFID, from Hornkoff Rd. east to the Nursery area, than in the western GFID area. Potatoes, cabbage, onions, and other vegetables are grown in this local area. According to Watson and Parsons (1991; pers comm) however, agricultural activity in the study area has generally declined in recent years.

In the eastern portion of the GFID, major growing areas include large potatoe fields south of the airport along Kenmore Rd. and south of the Burlington Northern railway between Kenmore Rd. and Seminoff Rd. A pickling onion field exists north of Carson Rd between Como Rd. and International Rd. These areas correspond with areas of high NO_3-N levels. Vegetables and tree orchards (fruit and ornamental) are grown in the Nursery area where elevated NO_3-N also occurs.

Agricultural activity in the western portion of the GFID is not as intensive. A large ornamental tree orchard exists south of Carson Rd. and west of Hornkoff Rd. According to Parsons and Watson (1991; pers comm), nurseries do not require as much fertilizers as vegetable crops. Nitrate-nitrogen levels around this nursery area appears quite low. Strawberry fields exist along the Kettle River. However, wells sampled in this area during the reconnaissance survey generally showed elevated levels of NO_3-N only in localized areas (Figure 13).

In the area north of the Kettle River, along North Fork Rd. at the western Grand Forks city limits, is another large potatoe field. Although a field value of 10 mg/L NO_3-N was detected in the Koftinoff well adjacent to this field, lab analysis of this well shows low NO_3-N values of 2.1 mg/L. However, field results of nearby wells also show elevated nitrate levels in groundwater. The impact of agricultural activity on groundwater in this local area is ill-defined due to lack of data points.



Province of British Columbia
Ministry of Environment
WATER MANAGEMENT BRANCH

GRAND FORKS AREA
PRELIMINARY AGRICULTURAL LAND-USE
FALL 1991

SCALE: 1:20000	DATE MARCH 1992
M.WEI ENGINEER	
FILE No. 0329563-A	DWG No. FIGURE 38

The Hunt well where elevated NO_3-N was detected from the lab analysis (6.5 mg/L) is in a residential area. The source of NO_3-N for that well is not obvious and may be from garden fertilizers, septic systems, or farms upgradient of the well. An inspection of the land use around the well head may help explain the results.

Source of NO_3-N

The broad extent of NO_3-N occurrence and the general decrease of NO_3-N with depth suggest that the source of nitrate in groundwater is derived from non-point sources above the water table. Two pieces of evidence suggest NO_3-N is from inorganic fertilizers:

1) association of NO_3-N with other chemicals typically found in inorganic fertilizers such as Ca and Mg (hardness), Cl, SO_4, and to some extent with K and F and
2) correlation of high nitrate areas with areas of vegetable farming.

Contribution of nitrogen from septic systems is not accurately known but is suspected to be minor; the density of rural homes in the study area is relatively low.

Implications to USA

Implications of groundwater contamination by nitrate movement directly south across the USA-Canada border appears negligible. In the study area, the Kettle River floodplain (and the aquifer) extends only a limited distance across the border. The regional groundwater flow in the GFID area adjacent to the border is generally to the north and east away from the border (Figure 5).

Recommendations

1) Sampling of the domestic wells on an annual basis and piezometers on a semi-annual basis should continue for monitoring temporal water quality trends in the aquifer,

2) Samples from domestic wells should also be analyzed for metals,

3) Sampling and monitoring of domestic and private wells should expand to include production wells in the GFID, Covert Irrigation District, Sion Improvement District, City of Grand Forks, and the area along North Fork Rd.,

4) To ascertain the source of NO_3-N and if denitrification is occurring at depth in the aquifer, the domestic wells and piezometers should also be sampled for ^{15}N, denitrifying bacteria, DOC, and redox potential,

5) Existing and any additional wells selected for sampling should be correlated with the CGDS database to ensure that well completion details are known,

6) A detailed land-use survey of the entire study area is recommended for documenting existing land-use and agricultural practices including pesticide use and estimating nitrogen loading into the aquifer,

7) Data from the Water Quality Check Program should also be reviewed to describe groundwater quality of the study area.

8) Regularly sampled domestic wells located near nurseries and orchards should also be analyzed for pesticides,

9) Although the existing 3 piezometer sites are adequate for investigating NO_3-N behavior at a local scale, an additional two piezometer sites are required near International Rd. and Kenmore Rd. to better delineate the NO_3-N plume south of the airport (Figure 11); estimated cost for their construction is approximately $25,000.

10) Instrumentation of the vadose zone in the area south of the airport is also recommended to track NO_3-N transport from the soil zone to the underlying aquifer.

11) Geochemical modeling is required to determine the association of NO_3-N with other chemical constituents and the possible chemical processes involved,

12) A numerical model should be developed to assess the effects of groundwater flow, development, and recharge on the water quality of the aquifer.

Acknowledgements

Mike Gallo helped compile the information on the hydrogeology of the Grand Forks study area. Bill McGinness drafted Figures 2,3,5,12-17, and 38. Tim Watson and John Parsons, Ministry of Agriculture provided helpful assistance in the preliminary land use survey.

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Appendix A

CGDS Well Log Summary of Grand Forks, B.C.

Ministry of Environment - Water Management Branch - Groundwater Section
Groundwater Database System
Data Summary - with Legal Descriptions and Old Coordinates

BCGS Map Area	Well No.	Lot No.	Plan No.	Blk No.	TP	SC	RG	D.L.	Z	X	Y	Old Well No.	L.D.	Owner's Name	Site Address	Date Constructed (dmy)	Well Depth (ft.)	Well Diam. (in.)	Drill Contr No.	Const. Method	Well Yield	Yld. Unt.	Depth to Water (ft.)	Depth to Bedrk (ft.)	Aquif Litho	Screen Interval (ft.)	G.W. Rpt	Chem Lab	Chem Fld	Chem Site No.
082E.009.1.3.1	002								01	17	11	002	52	WALTER MEHMAL	GRAND FORKS	03-09-76	388.0	6.0	058	DRI	65.0	GPM	105	UNK	UNC					

Ministry of Environment - Water Management Branch - Groundwater Section
Groundwater Database System
Data Summary - with Legal Descriptions and Old Coordinates

BCGS Map Area	Well No.	Lot No.	Plan No.	Blk No.	TP	SC	RG	D.L.	Z	X	Y	Old Well No.	L.D.	Owner's Name	Site Address	Date Constructed (dmy)	Well Depth (ft.)	Well Diam. (in.)	Drill Contr No.	Const. Method	Well Yield	Yld. Unt.	Depth to Water (ft.)	Depth to Bedrk (ft.)	Aquif Litho	Screen Interval (ft.)	G.W. Rpt	Chem Lab	Chem Fld	Chem Site No.
082E.008.2.3.4	002		B4427					333	01	17	19	002	52	DON HAIRSINE	GRAND FORKS	01-01-77	150.0	6.0	058	DRI	3.0	GPM	44	UNK	UNC					
082E.008.2.3.4	003	1	10383					1494	01	17	18	005	52	PAUL SOFONOFF	FRANKLIN RD N FORK	13-10-77	41.0	6.0	058	DRI	15.0	GPM	25	UNK	UNC	36-41				
082E.008.2.3.4	004	4	29798					1494	01	17	18	006	52	KATHLEEN REZANSOFF	BOX 395 GRAND FORKS	01-04-79	60.0	6.0	058	DRI	20.0	GPM	31	UNK	UNC	56-60				
082E.008.2.3.4	005	2	29798					1494	01	17	18	007	52	GEORGE ZIBIN	BOX 1600 GRAND FORKS	01-04-79	56.0	6.0	058	DRI	15.0	GPM	31	UNK	UNC	52-56				
082E.008.2.3.4	006	1	29798					1494	01	17	18	008	52	BOB BOWERING	BOX 1600 GRAND FORKS	01-04-79	74.0	6.0	058	DRI	15.0	GPM	39	UNK	UNC	70-74				
082E.008.2.3.4	007		A32					1494	01	17	19	004	52	PAUL HENDERSON		01-01-80	74.0	8.0	058	DRI	300.0	GPM	45	UNK	UNC	62-74				
082E.008.2.4.1	001			26				585	01	17	17	001	52	W DOCKSTEADER #1 WEL	E 8TH ST GRAND FORKS	01-08-53	32.0	6.5	021	DRI	20.0	IGM	8	UNK	UNC					
082E.008.2.4.1	002	108							01	17	17	003	52	PETER BOWEN	GRAND FORKS	07-07-69	61.0	8.0	120	DRI	40.0	GPM	33	UNK	UNC					
082E.008.2.4.1	003							382	01	17	08	006	52	CITY OF GRAND FORKS	GRAND FORKS	01-05-77	400.0	6.0	058	DRI			36	UNK	UNC					
082E.008.2.4.1	004		22	10				382	01	17	08	007	52	CITY OF GRAND FORKS		27-05-77	405.0	6.0	058	DRI	180.0	GPM	32	UNK	UNC	129-137				
082E.008.2.4.1	005	A	B5791					381	00	00	00	000	52	SCHOOL DIST. 12	PERLEY SCHOOL	23-10-81	70.6	8.0	066	DRI	122.0	GPM	22		UNC	59-70				
082E.008.2.4.2	001	1	3072					653	01	17	09	012	52	MAYFLOWER TRAILER PK		01-08-80	70.0	6.0	058	DRI	80.0	GPM	14	70	UNC	23-27				
082E.009.1.1.1	001	24	7226					715	01	17	02	002	52	J H PUSKEPPELIES	GRAND FORKS	22-04-72	58.0	6.0	109	DRI	5.0	GPM	UNK	57	UNC					
082E.009.1.1.1	002	A	B6630	2				2028	01	17	03	003	52	ALICCEY KOLMIKOFF	GRAND FORKS	01-09-80	54.0	6.0	058	DRI	40.0	GPM	15	UNK	UNC					
082E.009.1.1.1	003	24	7226					715	01	17	02	003	52	M. WELLS	WEST GILPIN RD.	01-01-72	21.0	6.0	109	DRI	10.0	GPM	UNK	UNK	UNC					
082E.009.1.1.1	004	24	726					715	00	00	00	000	52	JOHN PUSKEPPELIES	820 GILPIN RD.	24-07-89	205.0	6.0	028	DRI	2.0	GPM	137	72	BED					
082E.009.1.1.2	001	33	726					499	00	00	00	000	52	CARL MORRISON	GILPIN RD	23-04-81	30.0	6.0	111	DRI	20.0	GPM	20		UNC	26-30				
082E.009.1.1.3	001		3603	2				1475	01	17	03	002	52	FERN MORET	ATTWOOD RD GRAND FOR	08-04-77	37.0	6.0	058	DRI	16.0	GPM	21	UNK	UNC	29-34				
082E.009.1.1.3	002	19	726					715	01	17	11	003	52	JERRY SECRIST	GRAND FORKS	01-01-77	39.0	6.0	058	DRI			15	UNK	UNC					
082E.009.1.1.3	003	9	2087					184	01	17	10	004	52	FRED SIMINOFF		01-09-72	20.0	42.0	UNK	DUG			18	UNK	UNC					
082E.009.1.1.3	004	9	2087					184	01	17	10	005	52	DAVE GIBSON		01-01-50	20.4	42.0	UNK	DUG			18	UNK	UNC					
082E.009.1.1.3	005	8	82088					184	01	17	10	006	52	TIM REGANSOFF		01-01-50	15.8	42.0	UNK	DUG			14	UNK	UNC					
082E.009.1.1.3	006	4						184	01	17	10	009	52	PETE DE HAAN	GRAND FORKS	01-01-50	32.6	42.0	UNK				32	UNK	UNC					
082E.009.1.1.3	007	5						184	01	17	10	016	52	ZAITSOFF	GRAND FORKS	01-01-50	30.0	36.0	UNK	DUG			27	UNK	UNC					
082E.009.1.1.3	008	6						184	01	17	10	017	52	WILLIAM SAVITSKOFF	GRAND FORKS	01-01-50	33.4	42.0	UNK	DUG			31	UNK	UNC					
082E.009.1.1.3	009	6						184	01	17	10	018	52	ALEC STARCHUK	GRAND FORKS	01-01-50	39.3	42.0	UNK	DUG			36	UNK	UNC					
082E.009.1.1.3	010	7						184	01	17	10	019	52	PETE LAZAREFF		01-01-50	33.0	32.0	UNK	DUG			30	UNK	UNC					
082E.009.1.1.3	011	7						184	01	17	10	020	52	WALTER PARKER		01-01-50	38.7	36.0	UNK	DUG			36	UNK	UNC					
082E.009.1.1.3	012	9						184	01	17	10	021	52	JOSEPH NEGRAEFF	GRAND FORKS	01-01-50	13.1	18.0	UNK	DUG			11	UNK	UNC					
082E.009.1.1.3	013	9						184	01	17	10	022	52	ALEC DUTOFF	GRAND FORKS	01-03-73	14.0	28.0	UNK	DUG			13	UNK	UNC					
082E.009.1.1.3	014	10						184	01	17	10	023	52	HAROLD WALDO	GRAND FORKS	01-01-50	68.0	0.0	UNK	DUG			64	UNK	UNC					
082E.009.1.1.3	015	1	86026					184	01	17	10	024	52	LLOYD SOLBERG	GRAND FORKS	01-01-50	40.2	48.0	UNK	DUG			39	UNK	UNC					
082E.009.1.1.3	016							184	01	17	10	025	52	CLARENCE DOREN	GRAND FORKS	01-01-50	12.1	42.0	UNK	DUG			11	UNK	UNC					
082E.009.1.1.3	017							184	01	17	10	026	52	BRIAN GRANT	GRAND FORKS	01-01-50	14.0	36.0	UNK	DUG			12	UNK	UNC					
082E.009.1.1.3	018	1	12955					184	01	17	10	027	52	HENRY SILVESTER	GRAND FORKS	01-01-50	13.5	42.0	UNK	DUG			12	UNK	UNC					
082E.009.1.1.3	019							184	01	17	10	028	52	TOM SISKA	GRAND FORKS	01-01-50	56.0	36.0	UNK	DUG			45	UNK	UNC					
082E.009.1.1.3	020							184	01	17	10	029	52	GARY HUNT	GRAND FORKS	01-01-50	24.0	6.0	UNK	DRI			20	UNK	UNC					
082E.009.1.1.3	021							184	01	17	10	030	52	PETER STARCHUK	GRAND FORKS	01-01-50	64.4	48.0	UNK				62	UNK	UNC					
082E.009.1.1.3	022							184	01	17	10	031	52	FRED SWETLINOFF	GRAND FORKS	01-01-50	21.0	42.0	UNK	DUG			18	UNK	UNC					
082E.009.1.1.3	023	5	567	2				184	01	17	10	032	52	ALEX STARCHUK	STARCHUK RD GRAND FO	01-10-77	45.0	6.0	058	DRI	120.0	GPM	25	UNK	UNC	31-39				
082E.009.1.1.3	024	8	567	2				184	01	17	10	033	52	HARRY STONE	GRAND FORKS	03-10-77	44.0	6.0	058	DRI	12.0	GPM	25	UNK	UNC	33-37				
082E.009.1.1.3	025		B2088					184	01	17	10	034	52	BILL PARKER		01-01-79	40.0	0.0	058	DRI			UNK	UNK	UNC					
082E.009.1.1.3	026		B2088					184	01	17	10	035	52	BILL PARKER		01-04-79	40.0	0.0	058	DRI			UNK	UNK	UNC					
082E.009.1.1.3	027							184	01	17	10	015	52	JOHN ELZINGA	GRAND FORKS	01-01-50	46.6	42.0	UNK	DUG			44	UNK	UNC					
082E.009.1.1.3	028	8	817					1475	01	17	03	000	52	CHARLES GRUBISIC			18.5	0.0	UNK	DRI					UNC			Y		
082E.009.1.1.3	029	3	567					184	01	17	10	000	52	BRIAN GRANT			43.0	0.0	UNK	DRI					UNC			Y		
082E.009.1.1.4	001		B11423					350	01	17	02	001	52	RICHIE MANN	GRAND FORKS	21-08-77	32.0	6.0	058	DRI			14	UNK	UNC	21-26				
082E.009.1.3.1	001							351	01	17	11	001	52	WALTER MEHMAL	BOX 71 GRAND FORKS	08-01-69	50.0	8.0	120	DRI	10.0	GPM	14	UNK	UNC	28-46				

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BCGS Map Area	Well No.	Lot No.	Plan No.	Blk No.	TP	SC	RG	D.L.	Z	X	Y	Old Well No.	L.D.	Owner's Name	Site Address	Date Constructed (dmy)	Well Depth (ft.)	Well Diam. (in.)	Drill Contr No.	Const. Method	Well Yield	Yld. Unt.	Depth to Water (ft.)	Depth to Bedrk (ft.)	Aquif Litho	Screen Interval (ft.)	G.W. Rpt	Chem Lab	Chem Fld	Chem Site No.
082E.008.2.2.4	009	4						534	01	17	09	006	52	PHIL KOCH	GRAND FORKS	01-01-50	28.9	36.0	UNK	DUG			26	UNK	UNC					
082E.008.2.2.4	010	1						184	01	17	10	007	52	WINTER	GRAND FORKS	01-01-50	15.6	18.0	UNK	DUG			14	UNK	UNC					
082E.008.2.2.4	011	2	8735					534	01	17	09	007	52	GEORGE WOYKIN	GRAND FORKS	01-01-50	23.2	24.0	UNK	DUG			21	UNK	UNC					
082E.008.2.2.4	012							534	01	17	09	008	52	WES PLOTNIKOFF	GRAND FORKS	01-01-50	17.8	42.0	UNK	DUG			16	UNK	UNC					
082E.008.2.2.4	013	1	11624					184	01	17	10	008	52	FRED POZNIKOFF	GRAND FORKS	01-01-50	32.4	36.0	UNK	DUG			31	UNK	UNC					
082E.008.2.2.4	014		8735					534	01	17	09	009	52	HOWARD KEIM	GRAND FORKS	01-01-50	33.9	0.0	UNK				32	UNK	UNC					
082E.008.2.2.4	015	2						184	01	17	10	010	52	WILLIAM STARCHUK	GRAND FORKS	01-01-50	31.9	18.0	UNK	DUG			31	UNK	UNC					
082E.008.2.2.4	016	534	18181						01	17	09	010	52	AIRPORT?	GRAND FORKS	01-01-76	90.0	36.0	UNK	DUG			41	UNK	UNC					1401418
082E.008.2.2.4	017	3	8489					536	01	17	04	010	52	JOHN OGLOFF	GRAND FORKS	01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.4	018	2	1969					184	01	17	10	011	52	BILL MOUNTAIN	GRAND FORKS	01-01-50	43.0	42.0	UNK	DUG			UNK	UNK	UNC					
082E.008.2.2.4	019	4	18967					152	01	17	09	011	52	J KALBIK	NURSERY RD GRAND FOR	02-06-77	80.0	6.0	058	DRI			25	UNK	UNC	75-79				
082E.008.2.2.4	020	1	1969	1				184	01	17	10	012	52	WILLIAM YURKIW	GRAND FORKS	01-01-50	24.2	42.0	UNK	DUG			19	UNK	UNC					
082E.008.2.2.4	021	4						184	01	17	10	013	52	TOM BRANDEL	GRAND FORKS	01-01-50	32.9	32.0	UNK	DUG			31	UNK	UNC					
082E.008.2.2.4	022	14	888					152	01	17	04	013	52	JOHN OGLOFF	GRAND FORKS	01-01-50	17.0	0.0	UNK				10	UNK	UNC					
082E.008.2.2.4	023	5						184	01	17	10	014	52	H M STARCHUK	GRAND FORKS	01-01-50	33.6	36.0	UNK	DUG			33	UNK	UNC					
082E.008.2.2.4	024							536	01	17	04	022	52	CECIL GEROW	GRAND FORKS	01-01-50	18.1	36.0	UNK	DUG			17	UNK	UNC				Y	
082E.008.2.2.4	025							536	01	17	04	023	52	GEORGE POPOFF	GRAND FORKS	01-01-50	19.6	36.0	UNK	DUG			17	UNK	UNC					
082E.008.2.2.4	026							536	01	17	04	024	52	GEORGE POPOFF	GRAND FORKS	01-01-50	15.1	36.0	UNK	DUG			15	UNK	UNC					
082E.008.2.2.4	027							536	01	17	04	025	52	MIKE MALAKOFF	GRAND FORKS	01-01-50	38.0	42.0	UNK				33	UNK	UNC					
082E.008.2.2.4	028	11	B4896					536	01	17	04	021	52	JOHN OGLOFF	GRAND FORKS	01-01-50	49.0	24.0	UNK	DUG			37	UNK	UNC					
082E.008.2.2.4	029	3	817					1475	01	17	10	000	52	H FUNK			23.0	0.0	UNK	DRI					UNC			Y		
082E.008.2.2.4	030	A	13265					1475	00	00	00	000	52	HARVEY DENAMY	5784 NURSERY ROAD	24-03-87	30.0	6.0	036	DRI	50.0	GPM	10		UNC	24-29				
082E.008.2.2.4	031	A	1455	20				532	00	00	00	000	52	B ZAITSOFF	624 KENMORE ST.	10-09-88	41.0	4.0	007	DRI	35.0	GPM	21		UNC					
082E.008.2.3.1	001	3	8076					334	01	16	13	001	52	SION IMPROVEMENT DIS		01-01-67	345.0	10.0	UNK	DRI	250.0	GPM	42	UNK	UNC	273-293				
082E.008.2.3.1	002	1						334	01	16	13	003	52	GROUND-WATER DIV CON	VICTORIA	01-10-63	202.0	8.0	086	DRI			42	UNK	UNC					
082E.008.2.3.1	003	2	8076					334	01	16	00	004	52	SION IMPROVEMENT DIS		01-01-67	297.0	16.0	UNK	DRI	2000.0	GPM	39	UNK	UNC	267-297				
082E.008.2.3.1	004								01	16	12	004	52	KARCZ	GRAND FORKS	03-10-75	50.0	6.0	109	DRI	9.0	GPM	34	50	UNC	35-50				
082E.008.2.3.1	005	2	38	6				700	01	16	12	006	52	D SNEDDON	WEST GRAND FORKS	05-04-72	53.0	6.0	109	DRI	14.0	GPM	38	UNK	UNC	50-53				
082E.008.2.3.1	006	4	14842					700	01	16	13	007	52	T W HOLM	GRAND FORKS	14-07-76	62.0	6.0	058	OTH	30.0	GPM	38	UNK	UNC	56-60				
082E.008.2.3.1	007	3						700	01	16	13	008	52	P KOFTINOFF	N FORK FRANKLIN RD G	01-05-77	265.0	6.0	058	DRI	32.0	GPM	42	UNK	UNC	261-265				
082E.008.2.3.1	008	B	18227					700	01	16	13	000	52	LEN THEROUX	ANDROS RD	27-04-81	60.0	6.0	111		25.0	USGM	40	UNK	UNC					
082E.008.2.3.2	001	520							01	17	18	001	52	SUGIMOTO	6TH ST WEST GRAND FO	01-01-52	30.0	60.0	NA	DUG	300.0	GPM	22	UNK	UNC					1401419
082E.008.2.3.2	002		B7942					380	01	17	07	001	52	CITY OF GRAND FORKS	BOX 220 GRAND FORKS	01-06-77	230.0	8.0	058		560.0	USGM	36	UNK	UNC					
082E.008.2.3.2	003	1700							01	17	17	002	52	WM CHEVELDEAU	WEST GRAND FORKS	01-09-53	81.0	7.0	021	DRI	40.0	GPM	21	UNK	UNC					
082E.008.2.3.2	004	14	1339	8				520	01	17	18	003	52	CITY OF GRAND FORKS	GRAND FORKS	01-01-59	45.0	0.0	UNK	DUG			UNK	UNK	UNC			Y		
082E.008.2.3.2	005	15		21					01	17	07	003	52	CITY OF GRAND FORKS	GRAND FORKS	01-01-56	91.0	0.0	NA	DUG	750.0	USGM	17	UNK	UNC	41-59		Y		
082E.008.2.3.2	006	1	11877					520	01	17	18	004	52	BOUNDARY HOSPITAL	GRAND FORKS	24-08-76	111.0	6.0	066		90.0	GPM	40	UNK	UNC	103-111				
082E.008.2.3.2	007	520							01	17	07	004	52	GRAND FORKS TOWN #1	GRAND FORKS	01-01-67	35.0	0.0	152	DRI			17	UNK	UNC					
082E.008.2.3.2	008		213	33				700	01	16	13	005	52	GUS MALAKOFF	WEST GRAND FORKS	07-07-72	71.0	6.0	109	DRI	33.0	GPM	37	UNK	UNC	66-71				
082E.008.2.3.2	009	A	7378	33				700	01	16	13	006	52	P SOFONOFF	WEST GRAND FORKS	18-07-72	75.0	6.0	109	DRI	4.0	GPM	UNK	UNK	UNC	63-75				
082E.008.2.3.2	010								01	17	07	013	52	CITY OF GRAND FORKS	GRAND FORKS	16-04-65	100.0	16.0	021	DRI	500.0	GPM	40	UNK	UNC			Y		
082E.008.2.3.2	011							1700	01	17	18	009	52	P P PLOTNIKOFF	WEST GRAND FORKS	06-03-72	107.0	6.0	109	DRI	10.0	GPM	44	UNK	UNC	92-97				
082E.008.2.3.2	012							520	01	17	18	010	52	SUGIMOTO	6TH ST WEST GRAND FO	01-01-57	51.0	60.0	NA	DUG			43	UNK	UNC					
082E.008.2.3.2	013	2	11153					1494	01	17	18	011	52	J H HUGHES	GRAND FORKS	07-09-85	160.0	6.0	104	DRI			UNK	UNK	UNC					
082E.008.2.3.2	014		B2009					381	00	00	00	000	52	SCHOOL DISTRICT 12	CENTRAL AVE	23-10-81	77.0	8.0	066	DRI	125.0	GPM	13		UNC	60-77				
082E.008.2.3.3	001	24						334	01	16	13	002	52	GROUNDWATER DIVISION		01-08-63	100.0	8.0	086				8	UNK	UNC					
082E.008.2.3.3	002	29	8423					333	00	00	00	000	52	KIM MCLEAN	KOOCHIN OUTLOOK RD.	29-04-88	140.0	6.0	023	DRI	6.0	GPM	+	46	BED					
082E.008.2.3.4	001	1	22929					1494	01	17	18	002	52	G ZIBIN	GRAND FORKS	23-07-72	115.0	6.0	109	DRI			UNK	UNK	UNC					

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082E.008.2.2.1	023							536	01	17	04	020	52	ALFRED BAUER	GRAND FORKS	01-01-50	45.0	36.0	UNK	DUG			39	UNK	UNC					
082E.008.2.2.1	024							519	01	17	05	023	52	ROBERT RUDOLPH	CARSON RD	01-01-50	34.0	42.0	UNK	DUG			30	UNK	UNC					
082E.008.2.2.1	025	3	1721					519	01	17	05	026	52	J M JAGGERS	GRAND FORKS	01-01-50	48.0	42.0	UNK	DUG			46	UNK	UNC					
082E.008.2.2.1	026	10	110					535	01	17	05	028	52	G J BRUSSEL	833 E 6TH ST NORTH V	01-12-77	62.0	6.0	058	DRI	30.0	GPM	32	UNK	UNC	57-62				
082E.008.2.2.1	027	11	110					535	01	17	05	029	52	JIM BEGIN TRUMAN	GRAND FORKS	01-02-79	94.0	6.0	058	DRI	10.0	GPM	50	UNK	UNC	82-86				
082E.008.2.2.1	028		B4154A					519	01	17	05	030	52	HANS LODDER	GRAND FORKS	01-01-50	39.0	0.0	UNK	DUG			31	UNK	UNC					
082E.008.2.2.1	029							519	01	17	05	031	52	GEORGE VISSER	CARSON RD GRAND FORK	01-01-50	44.0	0.0	UNK	DUG			32	UNK	UNC					
082E.008.2.2.1	030		D4154					519	01	17	05	032	52	HENRY HARDER	CARSON RD GRAND FORK	01-01-50	27.0	42.0	UNK				26	UNK	UNC					
082E.008.2.2.1	031	2	17334					536	01	17	04	000	52	RANDALL KOHN		01-01-01	36.0	0.0	UNK	DRI			UNK	UNK	UNC			Y		
082E.008.2.2.1	033							519	00	00	00	000	52	GROUNDWATER SECTION	COMO RD.	25-11-89	60.0	6.0	047	DRI				UNK	UNC		Y			E20807081
082E.008.2.2.1	034							519	00	00	00	000	52	GROUNDWATER SECTION	COMO RD.	25-11-89	100.0	6.0	047	DRI				UNK	UNC		Y			E208068&9
082E.008.2.2.2	001	536							01	17	04	001	52	J WOODWARD	GRAND FORKS	01-07-53	39.0	6.0	021	DRI	2.0	IGM	18	UNK	UNC					
082E.008.2.2.2	002	7						536	01	17	04	002	52	PETRE TROFIMENKOFF	GRAND FORKS	01-01-63	40.0	27.0	152	DRI			UNK	UNK	UNC					
082E.008.2.2.2	003	7						536	01	17	04	003	52	P TROFIMENKOFF	GRAND FORKS	26-07-63	43.0	0.0	152	OTH			34	UNK	UNC					
082E.008.2.2.2	004							536	01	17	04	004	52	TONY LADDER	GRAND FORKS	01-01-50	198.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.2	005							536	01	17	04	005	52	TONY LADDER		01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.2	006	3	8489					536	01	17	04	009	52	JOHN OGLOFF	GRAND FORKS	01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.2	007	3	8489					536	01	17	04	011	52	JOHN OGLOFF	GRAND FORKS	01-01-50	88.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.2	008	14	888					152	01	17	04	012	52	JOHN OGLOFF	GRAND FORKS	01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.2	009							536	01	17	04	016	52	PETER KAZAKOFF	GRAND FORKS	01-01-50	36.0	42.0	UNK	DUG			36	UNK	UNC					
082E.008.2.2.2	010	A	2949					152	01	17	04	000	52	JOHN J OGLOFF		01-01-01	60.0	0.0	UNK	DRI					UNC			Y		
082E.008.2.2.2	011	B	2949					152	01	17	04	027	52	MARY KOLESNIKOFF	GRAND FORKS	01-02-78	72.0	6.0	058	DRI	10.0	GPM	34	UNK	UNC	61-65				
082E.008.2.2.3	001	534							01	17	06	001	52	OSCAR PENNOYER	CROWN MEAT MKT GRAND	01-01-57	142.0	6.0	021	DRI			UNK	UNK	UNC					
082E.008.2.2.3	002							519	01	17	05	001	52	ORSER-FAIR GROUNDS	GRAND FORKS	26-08-63	22.0	0.0	152	DUG			12	UNK	UNC					
082E.008.2.2.3	003	2	817					1475	01	17	03	001	52	ED BOOTHMAN	CASCADE RD	01-05-77	35.0	6.0	058	DRI			11	UNK	UNC	30-35				
082E.008.2.2.3	004							534	01	17	08	004	52	OSCAR PENNOYER	CROWN MEAT MKT GRAND	01-01-57	29.0	6.0	021	DRI			14	UNK	UNC			Y		E105920
082E.008.2.2.3	005							534	01	17	08	005	52	M ANDERSON	GRAND FORKS	01-08-63	50.0	0.0	152	DRI			45	UNK	UNC					
082E.008.2.2.3	006	4	11664					519	01	17	05	006	52	PETE OGLOFF	GRAND FORKS	01-01-50	60.0	0.0	UNK				50	UNK	UNC					
082E.008.2.2.3	007	1	8489					536	01	17	04	006	52	PAUL WISHLAW	GRAND FORKS	01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.3	008	2	11664					519	01	17	05	007	52	FRED OGLOFF	GRAND FORKS	01-01-50	48.0	0.0	UNK				36	UNK	UNC					
082E.008.2.2.3	009	12	75					534	01	17	08	008	52	J M COWLER	GRAND FORKS	12-08-76	97.0	6.0	058	DRI	20.0	GPM	46	UNK	UNC					
082E.008.2.2.3	010	3	4131					536	01	17	04	008	52	NICK ZILIUM	GRAND FORKS	01-01-50	52.0	0.0	UNK				40	UNK	UNC					
082E.008.2.2.3	011	B	26754					534	01	17	08	009	52	ALBERT MILLER	TRAIL	21-02-77	81.0	6.0	058	DRI	10.0	GPM	51	UNK	UNC	78-80				
082E.008.2.2.3	012	1	8159					519	01	17	05	024	52	PAUL KALESNIKOFF	GRAND FORKS	01-01-50	38.3	0.0	UNK	DUG			30	UNK	UNC					
082E.008.2.2.3	013		B1438					519	01	17	05	025	52	WILLIAM GLENN	GRAND FORKS	01-01-50	45.0	42.0	UNK	DUG			34	UNK	UNC					
082E.008.2.2.3	014	R	4131					536	01	17	04	026	52	FLORENCE BRYANT	GRAND FORKS	01-01-50	42.8	36.0	UNK	DUG			40	UNK	UNC					
082E.008.2.2.3	015		B4683					519	01	17	05	027	52	B C TELEPHONE	GRAND FORKS	24-06-76	97.0	6.0	059	DRI			51	UNK	UNC	80-84				
082E.008.2.2.3	016	2	29989					534	01	17	08	000	52	MIKE KABATOFF	JASPER AVENUE	15-05-81	85.0	6.0	111	DRI	15.0	USGM	52	UNK	UNC	81-85				
082E.008.2.2.3	017							382	00	00	00	000	52	GROUNDWATER SECTION	COMO RD.	25-11-89	60.0	6.0	047	DRI				UNK	UNC		Y			E208066&7
082E.008.2.2.3	018							382	00	00	00	000	52	GROUNDWATER SECTION	COMO RD.	25-11-89	100.0	6.0	047	DRI				UNK	UNC		Y			E208064&5
082E.008.2.2.4	001							184	01	17	10	001	52	JOHN SCHILLER	GRAND FORKS	01-01-67	27.0	0.0	152	DRI	30.0	GPM	7	UNK	UNC					
082E.008.2.2.4	002							534	01	17	09	001	52	BC FOREST SERVICE #1	GRAND FORKS	01-03-61	76.0	7.0	021	DRI			48	UNK	UNC					
082E.008.2.2.4	003							184	01	17	10	002	52	GEORGE MARKIN	GRAND FORKS	01-01-66	20.0	0.0	152	DRI			6	UNK	UNC					
082E.008.2.2.4	004							152	01	17	09	002	52	PETER POPOFF	GRAND FORKS	04-01-63	45.0	27.0	152	DRI			35	UNK	UNC					
082E.008.2.2.4	005							184	01	17	10	003	52	GEORGE MARKIN #2	GRAND FORKS	01-01-66	45.0	0.0	152	DUG			33	UNK	UNC					
082E.008.2.2.4	006							184	01	17	09	003	52	EMMANUEL ENTIMER	GRAND FORKS	01-01-50	30.0	0.0	UNK	DUG			26	UNK	UNC					
082E.008.2.2.4	007							534	01	17	09	004	52	PETER BOWEN	GRAND FORKS	01-01-50	61.5	8.0	UNK	DRI			38	UNK	UNC					
082E.008.2.2.4	008	2						534	01	17	09	005	52	ALEX SEMENOFF	GRAND FORKS	01-01-50	43.3	42.0	UNK	DUG			30	UNK	UNC					

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BCGS Map Area	Well No.	Lot No.	Plan No.	Blk No.	TP	SC	RG	D.L.	Z	X	Y	Old Well No.	L.D.	Owner's Name	Site Address	Date Constructed (dmy)	Well Depth (ft.)	Well Diam. (in.)	Drill Contr No.	Const. Method	Well Yield	Yld. Unt.	Depth to Water (ft.)	Depth to Bedrk (ft.)	Aquif Litho	Screen Interval (ft.)	G.W. Rpt	Chem Lab	Chem Fld	Chem Site No.
082E.008.2.1.3	004							700	01	16	12	005	52	JOHN HRUSHKIN	GRAND FORKS	14-11-76	63.0	6.0	058	DRI	12.0	GPM	38	UNK	UNC	59-63				
082E.008.2.1.3	005	6	2430					363	01	16	12	007	52	H KEBALO		01-05-79	42.0	6.0	058	DRI	40.0	GPM	10	UNK	UNC	34-38				
082E.008.2.1.3	006	2	38	9				700	00	00	00	000	52	R SMART	7180 SILVER ROAD	01-06-88	81.0	4.0	007	DRI	30.0	GPM	31		UNC					
082E.008.2.1.3	007	A	39217					700	00	00	00	000	52	T.WRIGHT	7175 SILVER RD.	10-06-88	68.0	4.0	007	DRI	15.0	GPM	32	UNK	UNC					
082E.008.2.1.4	001	3	69					533	01	17	07	002	52	ANDREW SEMINOFF	SW 7TH AVE GRAND FOR	20-07-72	60.0	6.0	109	DRI	50.0	GPM	35	UNK	UNC	55-60				
082E.008.2.1.4	002	380							01	17	07	005	52	GRAND FORKS TOWN #2	GRAND FORKS	01-01-67	70.0	0.0	152	DRI			12	UNK	UNC					
082E.008.2.1.4	003	500							01	17	07	006	52	ALEX GRITCHIN	RR 1 GRAND FORKS	01-09-63	60.0	8.0	086	DRI			UNK	54	UNC					
082E.008.2.1.4	004							500	01	17	07	007	52	MIKE CHIVELDEFF	GRAND FORKS	01-01-50	23.0	0.0	UNK				14	UNK	UNC	13-23				
082E.008.2.1.4	005							533	01	17	07	008	52	WILLIAM KONKEN	GRAND FORKS	01-01-50	41.0	42.0	UNK	DUG			40	UNK	UNC					
082E.008.2.1.4	006							500	01	17	06	008	52	MICKEY HORKOFF	GRAND FORKS	01-01-50	54.0	36.0	UNK	DUG			47	UNK	UNC	39-54				
082E.008.2.1.4	007	3						533	01	17	07	009	52	HELEN MARAZOFF	GRAND FORKS	01-01-50	8.0	0.0	UNK	DUG			8	UNK	UNC					
082E.008.2.1.4	008							500	01	17	06	009	52	MARY BOLINOFF	GRAND FORKS	01-01-50	54.0	42.0	UNK	DUG			49	UNK	UNC					
082E.008.2.1.4	009	533	B4206						01	17	07	010	52	CITY OF GRAND FORKS	GRAND FORKS	01-06-69	116.0	2.0	UNK	DRI	2000.0	GPM	21	UNK	UNC	92-112		Y		
082E.008.2.1.4	010	3						500	01	17	06	010	52	BOYD JOHNSON	GRAND FORKS	01-01-50	55.0	42.0	UNK	DUG			47	UNK	UNC	48-55				
082E.008.2.1.4	011	533							01	17	07	011	52	CITY OF GRAND FORKS	GRAND FORKS	01-06-69	127.0	8.0	UNK	DRI			UNK	UNK	UNC					1401504
082E.008.2.1.4	012							500	01	17	06	011	52	JOHN DOWEDOFF JR	GRAND FORKS	01-01-50	43.0	36.0	UNK	DUG			41	UNK	UNC					
082E.008.2.1.4	013	1	11697					533	01	17	07	012	52	N KINAKIN	ALMOND GARDENS GRAND	01-01-72	72.0	6.0	109	DRI	14.0	GPM	UNK	UNK	UNC					
082E.008.2.1.4	014	4	14938					500	01	17	06	012	52	ELI DOWEDOFF	GRAND FORKS	01-01-50	70.0	8.0	UNK	DRI			45	UNK	UNC					
082E.008.2.1.4	015	3						500	01	17	06	013	52	JOHN A DOVIDOFF	GRAND FORKS	01-01-50	43.0	36.0	UNK	DUG			41	UNK	UNC					
082E.008.2.1.4	016	12						500	01	17	06	016	52	MIKE CHURSINOFF	GRAND FORKS	01-01-50	55.0	8.0	UNK	DRI			43	UNK	UNC	42-55				
082E.008.2.1.4	017							500	01	17	06	017	52	POLLY KABATOFF	GRAND FORKS	01-01-50	50.0	42.0	UNK	DUG			48	UNK	UNC					
082E.008.2.1.4	018			5				500	01	17	06	018	52	ROBERT TURNBULL	GRAND FORKS	01-01-50	56.0	36.0	UNK	DUG			48	UNK	UNC	46-56				
082E.008.2.1.4	019			3				500	01	17	06	027	52	NICK PEPIN	GRAND FORKS	01-01-50	55.0	36.0	UNK	DUG			46	UNK	UNC	45-55				
082E.008.2.1.4	020							500	01	17	06	007	52	RICHARD KUHL	GRAND FORKS	01-01-50	58.0	6.0	UNK	DRI			46	UNK	UNC	45-58				
082E.008.2.1.4	021							500	01	17	06	036	52	JOE LABASH	GRAND FORKS	05-07-72	70.0	6.0	109	DRI	35.0	GPM	40	UNK	UNC	65-70				
082E.008.2.1.4	022	3	77					500	01	17	06	037	52	KEN SCHIVIEDER	GRAND FORKS	14-06-76	85.0	6.0	058	DRI	20.0	GPM	44	UNK	UNC	79-84				
082E.008.2.2.1	001	535							01	17	05	002	52	BROADACRES FARMS	GRAND FORKS	01-07-65	98.0	16.0	021		325.0	USGM	34	UNK	UNC					
082E.008.2.2.1	002		16307					519	01	17	05	003	52	JOHN KOTTINOFF	GRAND FORKS	01-01-50	50.0	0.0	UNK				40	UNK	UNC					
082E.008.2.2.1	003		529					519	01	17	05	004	52	JOHN SOOKOCHOFF	GRAND FORKS	01-01-50	40.0	0.0	UNK				30	UNK	UNC					
082E.008.2.2.1	004							519	01	17	05	005	52	MCKINNEY FARMS	GRAND FORKS	01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.1	005		5040					536	01	17	04	007	52	GEORGE WLASOFF	GRAND FORKS	01-01-50	50.0	0.0	UNK				32	UNK	UNC					
082E.008.2.2.1	006		11100					535	01	17	05	008	52	WALLACE DERQAUSOFF	GRAND FORKS	01-01-50	40.0	0.0	UNK				35	UNK	UNC					
082E.008.2.2.1	007	10	110					535	01	17	05	009	52	CHARLES ESOULOFF		01-01-50	40.0	0.0	UNK				30	UNK	UNC					
082E.008.2.2.1	008							535	01	17	05	012	52	PETE ESOULOFF	GRAND FORKS	01-01-50	35.0	0.0	UNK				28	UNK	UNC					
082E.008.2.2.1	009		14435					535	01	17	05	013	52	GEORGE MORTSOFF	GRAND FORKS	01-01-50	0.0	0.0	UNK				UNK	UNK	UNC					
082E.008.2.2.1	010		4154					519	01	17	05	014	52	WILLIAM BERESCHAGIN	GRAND FORKS	01-01-50	41.0	36.0	UNK	DUG			40	UNK	UNC					
082E.008.2.2.1	011	5						536	01	17	04	014	52	ALEC DERGAUSOFF	GRAND FORKS	01-01-50	30.0	42.0	UNK	DUG			28	UNK	UNC					
082E.008.2.2.1	012	14	140					500	01	17	06	014	52	WILLIAM J KRUKOFF	GRAND FORKS	01-01-50	44.0	36.0	UNK	DUG			43	UNK	UNC					
082E.008.2.2.1	013							519	01	17	05	015	52	PETE DUTOFF	GRAND FORKS	01-01-50	45.0	42.0	UNK	DUG			32	UNK	UNC					
082E.008.2.2.1	014	1	2821					535	01	17	05	016	52	PETER DERGOUSOFF	GRAND FORKS	01-01-50	50.0	0.0	UNK	DUG			40	UNK	UNC					
082E.008.2.2.1	015							536	01	17	04	015	52	GEORGE WLASOFF	GRAND FORKS	01-01-50	48.0	0.0	UNK	DUG			38	UNK	UNC					
082E.008.2.2.1	016	1	2821					535	01	17	05	017	52	JOHN HAMER	GRAND FORKS	01-01-50	33.0	18.0	UNK	DUG			31	UNK	UNC					
082E.008.2.2.1	017	3	179					535	01	17	04	017	52	NICK ABETKOFF	GRAND FORKS	01-01-50	33.0	24.0	UNK	DUG			30	UNK	UNC					
082E.008.2.2.1	018	2	2108					535	01	17	05	018	52	WILLIAM DERHOUSOFF	GRAND FORKS	01-01-50	31.0	36.0	UNK	DUG			29	UNK	UNC					
082E.008.2.2.1	019	8	2782					536	01	17	04	018	52	NICK PERVERSOFF	GRAND FORKS	01-01-50	33.0	30.0	UNK	DUG			32	UNK	UNC					
082E.008.2.2.1	020		B4388					535	01	17	05	019	52	PETER SIMINOFF	GRAND FORKS	01-01-50	51.0	6.0	UNK	DRI			35	UNK	UNC					
082E.008.2.2.1	021	8	B5060					536	01	17	04	019	52	GEORGE HORKOFF	GRAND FORKS	01-01-50	50.0	42.0	UNK	DUG			41	UNK	UNC					
082E.008.2.2.1	022	A	2821					535	01	17	05	020	52	PETER DERGOUSOFF	GRAND FORKS	01-01-50	38.0	42.0	UNK	DUG			33	UNK	UNC					

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BCGS Map Area	Well No.	Lot No.	Plan No.	Blk No.	TP	SC	RG	D.L.	Z	X	Y	Old Well No.	L.D.	Owner's Name	Site Address	Date Constructed (dmy)	Well Depth (ft.)	Well Diam. (in.)	Drill Contr No.	Const. Method	Well Yield	Yld. Unt.	Depth to Water (ft.)	Depth to Bedrk (ft.)	Aquif Litho	Screen Interval (ft.)	G.W. Rpt	Chem Lab	Chem Fld	Chem Site No.
082E.008.2.1.1	001							362	01	16	01	001	52	FRANCOIS MARCHAL	GRAND FORKS	01-01-50	70.0	36.0	UNK	DUG			62	UNK	UNC				Y	1401157
082E.008.2.1.1	002	2		18				367	01	16	01	002	52	JOHN MAKORTOFF	GRAND FORKS	01-01-50	50.1	42.0	UNK	DUG			46	UNK	UNC				Y	
082E.008.2.1.1	003	517							01	16	02	003	52	ALEX STRUKOFF	GRAND FORKS	01-01-50	20.0	0.0	152	DUG			8	UNK	UNC				Y	
082E.008.2.1.1	004	21						363	01	16	01	003	52	ALEC DEMOSKOFF		01-01-50	51.0	6.0	UNK	DRI			45	UNK	UNC					
082E.008.2.1.1	005	1	6263					363	01	16	01	004	52	PETER CHERNOFF	GRAND FORKS	01-01-50	53.6	36.0	UNK	DUG			50	UNK	UNC				Y	
082E.008.2.1.1	006	AB	15785					363	01	16	01	005	52	EDMOND BADER	GRAND FORKS	01-01-50	50.9	36.0	UNK	DUG			50	UNK	UNC				Y	
082E.008.2.1.1	007	B	23300					362	01	16	01	006	52	T G EATON	GRAND FORKS	01-01-50	60.0	4.0	UNK	DRI			45	UNK	UNC				Y	
082E.008.2.1.1	008	1		18				363	01	16	01	007	52	E T CARTER	GRAND FORKS	01-01-50	43.1	36.0	UNK	DUG			41	UNK	UNC				Y	
082E.008.2.1.1	009		12589					362	01	16	01	008	52	BRIAN KENNELLY	GRAND FORKS	01-01-50	36.8	36.0	UNK	DUG			34	UNK	UNC				Y	
082E.008.2.1.1	010								01	16	02	008	52	WALTER THOMAS		13-08-76	51.0	6.0	058	DRI			12	UNK	UNC					
082E.008.2.1.1	011	6	2430					363	01	16	01	009	52	H KEBALO	1633 HARBOUR DR PORT	01-05-79	22.0	12.0	058	DRI			10	UNK	UNC					
082E.008.2.1.1	012	1	39	12				517	01	16	02	014	52	MIKE ANDERSOV	GRAND FORKS	01-01-77	60.0	6.0	058	DRI	15.0	GPM	29	UNK	UNC	55-60				
082E.008.2.1.1	013	1	39	1				517	01	16	02	015	52	FRED POPOFF	GRAND FORKS	20-04-77	57.0	6.0	058	DRI			15	UNK	UNC	52-57				
082E.008.2.1.1	014	1	25485					362	00	00	00	000	52	JOHN H. DIAMOND	GRAND FORKS	16-07-76	44.0	0.0	058	DRI					UNC					
082E.008.2.1.2	001	500							01	17	06	001	52	WALTER HOODIKOFF	GRAND FORKS	18-11-68	62.0	6.0	109	DRI	25.0	GPM	45	UNK	UNC					
082E.008.2.1.2	002							500	01	17	06	002	52	JOHN SOLOUEOFF	GRAND FORKS	01-01-50	52.0	36.0	UNK	DUG			41	UNK	UNC	40-52				
082E.008.2.1.2	003	1		15				500	01	17	06	003	52	JOHN CLARK		01-01-50	31.0	42.0	UNK	DUG			29	UNK	UNC					
082E.008.2.1.2	004	2		15				500	01	17	06	004	52	STEVE GEVATKOFF	GRAND FORKS	01-01-50	41.0	42.0	UNK	DUG			39	UNK	UNC					
082E.008.2.1.2	005							500	01	17	06	005	52	GEORGE LOBEY	GRAND FORKS	01-01-50	46.0	36.0	UNK	DUG			40	UNK	UNC	39-46				
082E.008.2.1.2	006							500	01	17	06	006	52	PETER TACK	GRAND FORKS	01-01-50	41.0	42.0	UNK	DUG			40	UNK	UNC					
082E.008.2.1.2	007							500	00	00	00	000	52	GROUNDWATER SECTION	HORKOFF RD.	25-11-89	60.0	6.0	047	DRI				UNK	UNC		Y			E20806283
082E.008.2.1.2	008	9	110					535	01	17	05	010	52	C A PENNOYER	GRAND FORKS	01-01-50	45.0	0.0	UNK				34	UNK	UNC					
082E.008.2.1.2	009	13	110					535	01	17	05	011	52	PETE ESOULOFF	GRAND FORKS	01-01-50	38.0	0.0	UNK				30	UNK	UNC					
082E.008.2.1.2	010		77	11				500	01	17	06	015	52	PETER NEGRAEFF	GRAND FORKS	01-01-50	67.0	6.0	UNK	DRI			50	UNK	UNC					
082E.008.2.1.2	011							500	01	17	06	019	52	WALTER HOUDIKOFF	GRAND FORKS	01-01-50	50.0	6.0	109	DRI			42	UNK	UNC					
082E.008.2.1.2	012							500	01	17	06	020	52	NICKRANKOFF	GRAND FORKS	01-01-50	53.0	42.0	UNK	DUG			47	UNK	UNC					
082E.008.2.1.2	013			3				500	01	17	06	021	52	W PLOTNIKOFF	GRAND FORKS	10-04-72	65.0	6.0	109	DRI	10.0	GPM	46	UNK	UNC	60-65				
082E.008.2.1.2	014	1	110					535	01	17	05	021	52	LEO POH	CARSON RD	01-01-50	62.0	6.0	UNK	DRI			UNK	UNK	UNC					
082E.008.2.1.2	015							519	01	17	05	022	52	LEO POH	CARSON RD	01-01-50	64.0	0.0	UNK	DUG			48	UNK	UNC					
082E.008.2.1.2	016			7				500	01	17	06	022	52	PETER J DEMOSKOFF	GRAND FORKS	01-01-50	56.0	42.0	UNK	DUG			45	UNK	UNC	48-56				
082E.008.2.1.2	017	1	14873					500	01	17	06	023	52	BILL HOODIKOFF	GRAND FORKS	01-01-50	45.0	42.0	UNK	DUG			42	UNK	UNC					
082E.008.2.1.2	018							500	01	17	06	024	52	LEWIE JMAIFF	GRAND FORKS	01-01-50	62.0	42.0	UNK	DUG			45	UNK	UNC					
082E.008.2.1.2	019	8						500	01	17	06	025	52	FRANK PLOTNIKOFF	GRAND FORKS	01-01-50	40.0	24.0	UNK	DUG			38	UNK	UNC					
082E.008.2.1.2	020							500	01	17	06	026	52	PETER DUBOSOFF	GRAND FORKS	01-01-50	45.0	36.0	UNK	DUG			42	UNK	UNC					
082E.008.2.1.2	021							530	01	17	06	028	52	BIG Y GROWERS	GRAND FORKS	01-01-50	100.0	4.5	123				UNK	UNK	UNC					
082E.008.2.1.2	022							530	01	17	06	029	52	BIG Y GROWERS	GRAND FORKS	01-01-50	253.0	4.5	123				UNK	UNK	UNC					
082E.008.2.1.2	023							530	01	17	06	030	52	BIG Y GROWERS	GRAND FORKS	01-01-50	80.0	0.0	123				UNK	UNK	UNC					
082E.008.2.1.2	024							530	01	17	06	031	52	BIG Y GROWERS	GRAND FORKS	01-01-50	62.0	4.5	123				UNK	UNK	UNC					
082E.008.2.1.2	025							530	01	17	06	032	52	BIG Y GROWERS	GRAND FORKS	01-01-50	80.0	4.5	123				UNK	UNK	UNC					
082E.008.2.1.2	026								01	17	06	033	52	BIG Y GROWERS	GRAND FORKS	01-01-50	80.0	4.5	123				UNK	UNK	UNC					
082E.008.2.1.2	027								01	17	06	034	52	BIG Y GROWERS	GRAND FORKS	01-01-50	83.0	8.0	123		500.0	GPM	35	UNK	UNC					1401158
082E.008.2.1.2	028								01	17	06	035	52	BIG Y GROWERS	GRAND FORKS	01-01-50	90.0	8.0	123		600.0	GPM	30	UNK	UNC					
082E.008.2.1.2	029		77	2				500	01	17	06	038	52	LOIE JMAIFF	GRAND FORKS	20-11-74	66.0	8.0	109	DRI	30.0	GPM	47	UNK	UNC	60-65				
082E.008.2.1.2	030							500	00	00	00	000	52	GROUNDWATER SECTION	HORKOFF RD.	25-11-89	100.0	6.0	047	DRI				UNK	UNC		Y			E20806081
082E.008.2.1.2	031	1	3425					530	00	00	00	000	52	GRAND FORKS IRR.DIST	BIG Y AREA	15-02-87	183.0	8.0	036	DRI	1002.0	GPM	34	UNK	UNC	111-183				
082E.008.2.1.3	001		7888					1699	01	16	12	001	52	DOUKOBOR CO-OP ASSOC	COMMUNITY CENTRE GRA	01-01-60	44.0	33.0	UNK	DUG			38	UNK	UNC					
082E.008.2.1.3	002	453							01	16	12	002	52	JOHN KALMAKOFF	GRAND FORKS	01-01-50	64.0	7.0	021	DRI	40.0	GPM	40	UNK	UNC					
082E.008.2.1.3	003	1	7801					453	01	16	12	003	52	GROUND WATER DIV CON	VICTORIA	13-06-63	135.0	6.0	086	DRI			41	UNK	UNC					

Appendix B

Results of Laboratory Analysis of Samples from the Domestic Wells-May, 1989

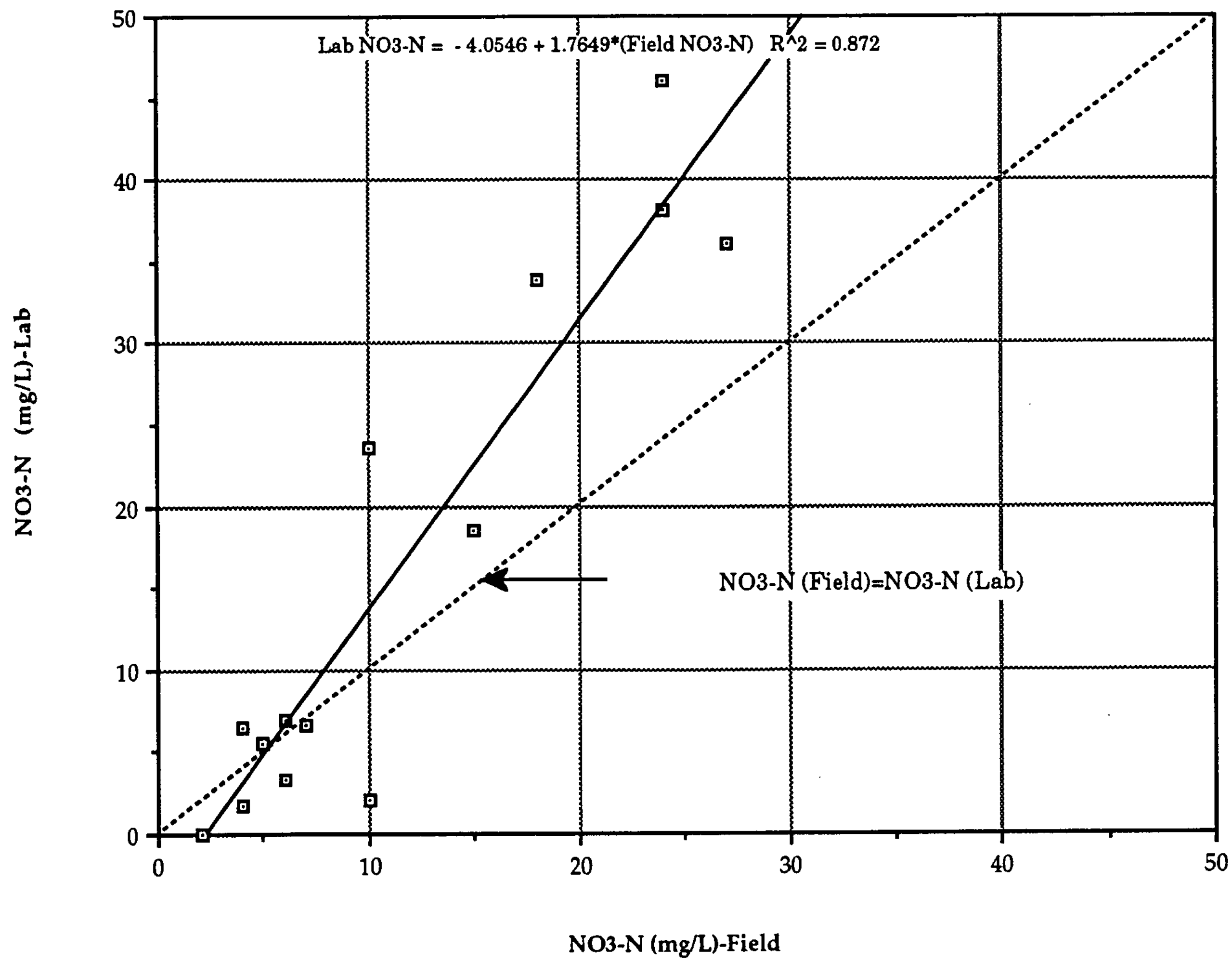
Appendix B. Laboratory Results of Initial Sampling of Domestic Wells and Piezometers

Seam No.	Well	Sample Date	Physical Parameters						Major Ions							Minor Constituents			Nitrogen							Sampling Method
		(m/d/y)	Spec. Cond.	Res. Filt.	pH	Alk. Tot.	Alk. Phen.	Hardness	Ca diss.	Mg diss.	Na diss.	K diss.	Cl diss.	SO4 diss.	HCO3	Silica Reac.	F diss.	Phos. tot. diss.	N org. tot.	N Kjel. tot.	N tot.	N amm. diss.	NO2-N diss.	NO3-N diss.	(NO2+NO3)-N diss.	
			(uS/cm)	(mg/L)	(-)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	From tap
E207827	Friesen	3-May-89	815	534	7.5	246.0	<0.5				39.0	9.1	25.2	64.0	300.1	20.7	0.53	0.372	0.31	0.31	23.9	<0.005	<0.005	23.6	23.6	From tap
E207828	Denamy	3-May-89	625	402	7.8	248.0	<0.5				28.1	3.9	9.8	48.0	302.6	21.7	0.45	0.045	0.07	0.07	7.07	<0.005	<0.005	7.0	7.0	From tap
E207829	Koftinoff	3-May-89	635	390	8.1	285.0	<0.5				18.0	3.5	5.2	47.7	347.7	20.3	0.59	0.027	0.08	0.08	2.2	<0.005	0.022	2.1	2.1	From tap
E207830	Hunt	3-May-89	480	262	8.0	178.0	<0.5				10.4	1.8	13.1	25.5	217.2	16.2	0.2	0.008	0.05	0.05	6.55	<0.005	<0.005	6.5	6.5	From tap
E207831	Popoff	4-May-89	165	112	7.5	77.1	<0.5				3.9	1.1	1.1	9.0	94.1	14.7	0.24	0.005	0.04	0.05	<0.07	0.015	<0.005	<0.02	<0.02	From tap
E207832	Gesser	4-May-89	365	212	8.0	146.0	<0.5				7.4	1.6	9.6	17.6	178.1	15.3	0.21	0.011	0.07	0.07	1.83	<0.005	<0.005	1.8	1.8	From tap
E207833	Gritchen	4-May-89	405	234	8.0	150.0	<0.5				7.5	1.7	7.6	23.7	183.0	20.2	0.19	0.036	0.07	0.07	5.63	<0.005	<0.005	5.6	5.6	From tap
E207834	Walker	4-May-89	355	218	8.1	147.0	<0.5				6.5	1.5	2.4	19.9	179.3	16	0.33	0.013	0.06	0.06	3.46	<0.005	<0.005	3.4	3.4	From tap
E207835	Soloveoff	4-May-89	450	278	8.1	153.0	<0.5				7.9	1.9	5.8	43.3	186.7	16.9	0.41	0.012	0.03	0.03	6.73	<0.005	<0.005	6.7	6.7	From tap
E207836	Lodder	4-May-89	650	418	7.9	182.0	<0.5				12.0	3.0	22.8	47.5	222.0	20.4	0.44	0.010	0.29	0.29	18.8	<0.005	<0.005	18.5	18.5	From tap
E207837	Ogloff	4-May-89	910	624	8.0	160.0	<0.5				27.0	4.1	32.1	76.3	195.2	16	0.61	0.010	0.11	0.11	46.1	<0.005	<0.005	46.0	46.0	From tap
E207838	Verigin	4-May-89	780	554	8.0	161.0	<0.5				19.0	3.9	25.5	60.5	196.4	19.1	0.41	0.018	0.11	0.11	36.1	<0.005	<0.005	36.0	36.0	From tap
E207839	Cleary	4-May-89	800	562	7.9	163.0	<0.5				16.1	4.0	23.9	60.0	198.9	18.2	0.39	0.016	0.98	0.98	39.2	<0.005	<0.005	38.2	38.2	From tap
E207840	Hale	4-May-89	1100	702	7.9	301.0	<0.5				4.5	4.4	46.5	89.8	367.2	22.2	0.59	0.125	0.25	0.25	34.1	<0.005	0.006	33.8	33.8	From tap
Seam No.	Well	Sample Date	Physical Parameters						Major Ions							Minor Constituents			Nitrogen							Sampling Method
		(m/d/y)	Spec. Cond.	Res. Filt.	pH	Alk. Tot.	Alk. Phen.	Hardness	Ca diss.	Mg diss.	Na diss.	K diss.	Cl diss.	SO4 diss.	HCO3	Silica Reac.	F diss.	Phos. tot. diss.	N org. tot.	N Kjel. tot.	N tot.	N amm. diss.	NO2-N diss.	NO3-N diss.	(NO2+NO3)-N diss.	
			(uS/cm)	(mg/L)	(-)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	Bailed
E208060	A-100	22-May-90	426	252	8	151	<0.5	196	55.3	14	2.2	0.6	0.8	39.5	184.22	11.3	0.43	<0.003	0.46	0.47	3.55	0.015	<0.005	3.08	3.08	Bailed
E208061	A-80	21-May-90	433	284	8	157	<0.5	197	52.7	16	9.5	2.3	5	41.9	191.54	16.7	0.49	0.004	0.49	0.5	3.95	0.015	0.015	3.44	3.45	Bailed
E208062	A-60	21-May-90	472	302	7.9	153	<0.5	217	59.8	16.4	8.2	2.2	6.4	34.6	186.66	19.7	0.43	0.004	0.37	0.38	11.3	0.013	0.014	10.9	10.9	Bailed
E208063	A-40	21-May-90	387	262	7.9	185	<0.5	199	57.4	13.6	8.5	2.1	4.4	13.3	225.7	20.1	0.44	0.012	0.59	0.6	3.95	0.013	0.006	3.34	3.35	Bailed
E208064	B-100	23-May-90	375	220	8	142	<0.5	162	47.2	10.8	11.9	3	4.9	34.1	173.24	17.1	0.55	0.007	0.19	0.22	0.26	0.025	0.009	0.03	0.04	Bailed
E208065	B-80	23-May-90	165	110	7.9	79	<0.5	85.2	28	3.7	5.1	2	0.8	8	96.38	12.8	0.67	0.004	0.01	0.02	<0.04	0.009	<0.005	<0.02	<0.02	Bailed
E208066	B-60	22-May-90	182	114	8	82.4	<0.5	94.6	30.4	4.55	3.9	1.2	1.1	11.2	100.528	13.4	0.6	0.003	0.19	0.19	0.63	<0.005	<0.005	0.44	0.44	Bailed
E208067	B-40	22-May-90	444	276	7.8	179	<0.5	182	54.1	11.3	17.7	2.4	11.8	20.1	218.38	30.2	0.16	0.285	0.56	0.58	3.03	0.023	<0.005	2.45	2.45	Bailed
E208068	C-100	24-May-90	370	240	7.8	166	<0.5	187	51.9	14	8.4	2.3	2.3	30.8	202.52	22.4	0.55	0.02	0.19	0.29	0.42	0.1	0.032	0.1	0.13	Bailed
E208069	C-80	24-May-90	480	346	8	142	<0.5	245	68.7	17.8	10.7	3.1	1.2	107	173.24	21.9	0.4	0.019	0.18	0.19	0.21	0.014	<0.005	<0.02	0.02	Bailed
E208070	C-60	24-May-90	510	318	7.9	171	<0.5	207	59.1	14.4	33.3	4.3	36.9	33.5	208.62	18.2	0.53	<0.003	0.33	0.39	2.82	0.058	0.141	2.29	2.43	Bailed
E208071	C-40	23-May-90	715	464	7.8	242	<0.5	328	90.8	24.5	23.9	4	18.4	56.4	295.24	24.9	0.42	0.115	0.31	0.31	16.1	<0.005	0.007	15.8	15.8	Bailed

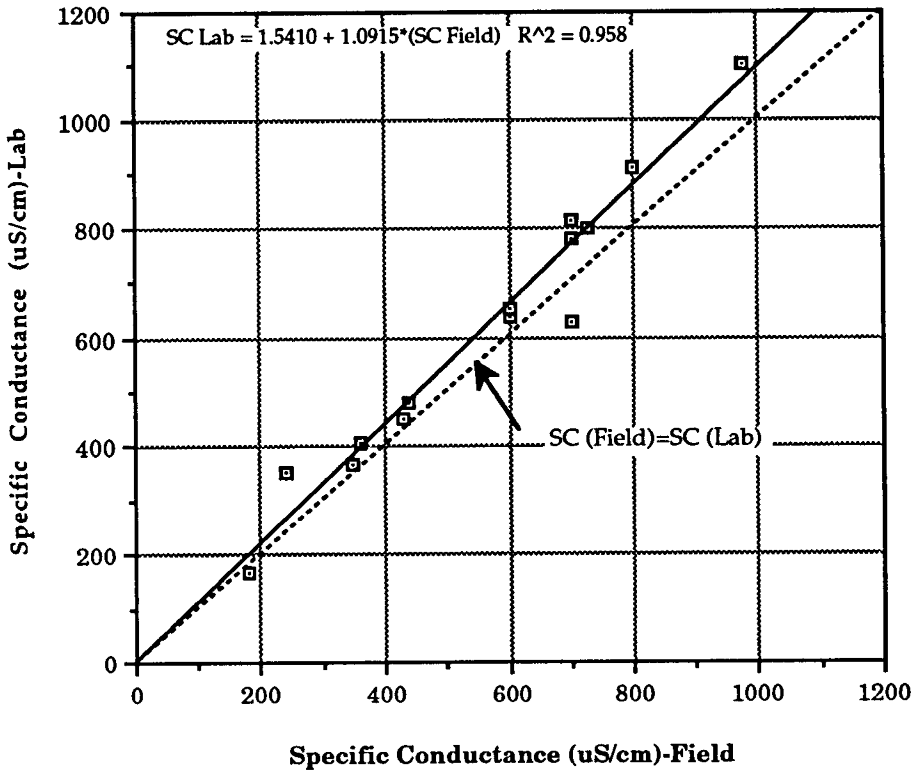
Appendix C

Correlation between Field & Lab Results of Samples from the Domestic Wells-May, 1989

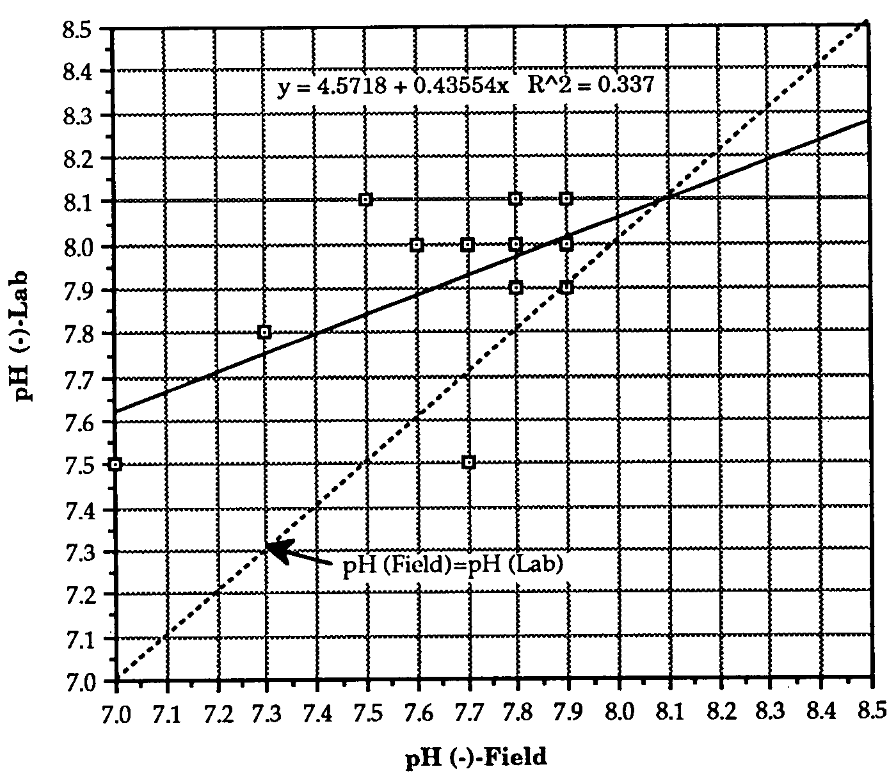
Correlation between Field and Lab Results- May, 1989



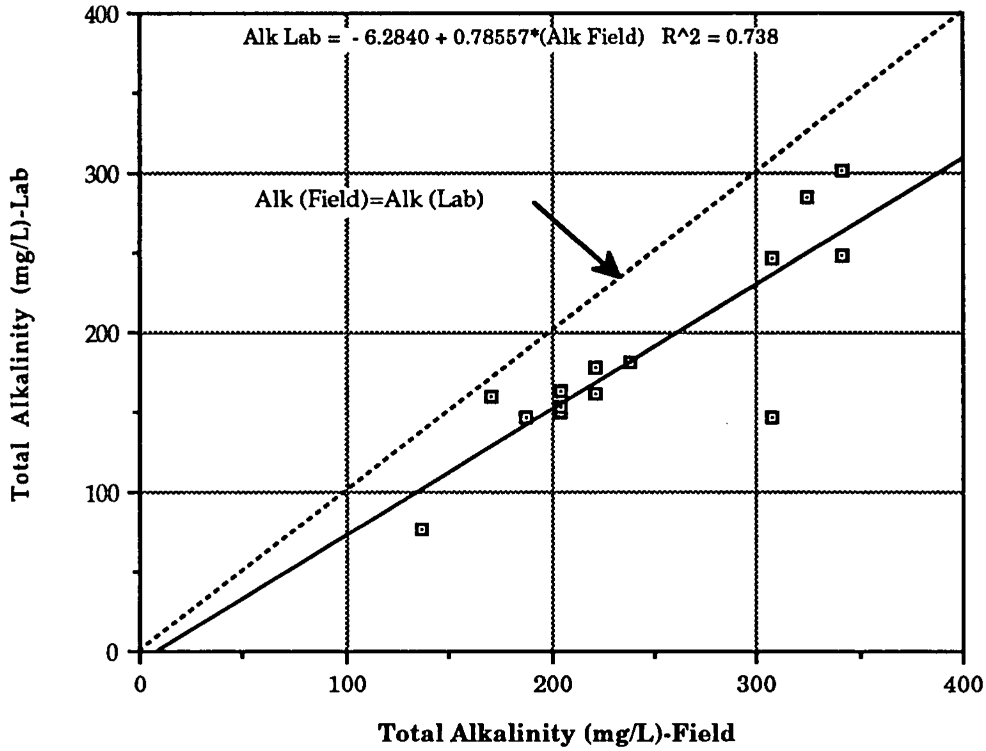
Correlation between Field and Lab Results-May, 1989



Correlation between Field and Lab Results-May, 1989



Correlation between Field and Lab Results-May, 1989



Correlation between Field and Lab Results-May, 1989