Legend to symbol, sample location, date, sample collector and analyzing laboratory for data shown on trilinear diagrams (see figures 8 - 11 in text).

FIGURE 8

SYMBOL	SAMPLE LOCATION	DATE	SAMPLE COLLECTOR	ANALYTICAL LABORATORY
A	CITY WELL	09-05-75	OFFICE OF ENVIRONMENTAL HEALTH	PUBLIC HEALTH LAB, JUNEAU, AK
B	CITY WELL	01-20-78	ALASKA AREA NATIVE HEALTH SERV.	CHEM & GEO LAB OF ALASKA
C	CITY WELL	09-05-79	ADEC/VILLAGE SAFE WATER	DEC DOUGLAS LAB
D	CITY WELL	05-22-81	ALASKA AREA NATIVE HEALTH SERV.	CHEM & GEO LAB OF ALASKA
E	CITY WELL	12-21-82	ALASKA AREA NATIVE HEALTH SERV.	CHEM & GEO LAB OF ALASKA
F	CITY WELL	09-01-85	ALASKA AREA NATIVE HEALTH SERV.	CHEM & GEO LAB OF ALASKA
G	CITY WELL	07-24-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
H	CITY WELL	07-29-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
I	CITY WELL	09-20-94	DNR/AHS FOR DEC/VSW	NORTHERN TESTING LAB

FIGURE 9

SYMBOL	SAMPLE LOCATION	DATE	SAMPLE COLLECTOR	ANALYTICAL LABORATORY
A	BIA WELL	08-01-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
B	WW-2	08-31-94	DNR/AHS FOR DEC/VSW	NORTHERN TESTING LAB
C	WW-2	08-31-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
D	WW-3	09-20-94	DNR/AHS FOR DEC/VSW	NORTHERN TESTING LAB
E	WW-3	09-21-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS

FIGURE 10

SYMBOL	SAMPLE LOCATION	DATE	SAMPLE COLLECTOR	ANALYTICAL LABORATORY
A	CITY WELL	07-29-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
B	BIA WELL	08-01-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
C	KINIA RIVER, HIGH TIDE	08-02-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS

FIGURE 11

SYMBOL	SAMPLE LOCATION	DATE	SAMPLE COLLECTOR	ANALYTICAL LABORATORY
M	KINIA RIVER, LEFT EDGE OF WATER, NEAR DATAPOD SENSOR, ~ 200' FROM BIA SCHOOL	07-26-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
H	KINIA RIVER, MID-CHANNEL @ HIGH TIDE SAMPLED AT 18' DEPTH	08-02-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS
L	KINIA RIVER, MID-CHANNEL @ LOW TIDE SAMPLED AT 15' DEPTH	08-02-94	DNR/ALASKA HYDROLOGIC SURVEY	WATER QUALITY LAB, FAIRBANKS

Title: CHEFORNAK CITY WELLS

Chemical Constituents in ppm

Sample	Date	Symbol	Ca	Mg	Na	K	HCO3	CO3	SO4	Cl	NO3	PO4	Si	Fe
CITY WELL	09/05/1975	A	5.00	16.00	136.00	0.00	287.00	0.00	13.00	102.00	0.06	10.00	0.00	0.23
CITY WELL	01/20/1978	B	12.00	14.00	121.00	14.00	305.00	0.00	4.00	130.00	0.00	0.00	0.00	0.03
CITY WELL	09/05/1979	C	6.20	15.90	138.00	13.90	280.60	0.00	0.00	168.00	1.00	0.00	0.00	0.30
CITY WELL	05/22/1981	D	5.20	12.00	100.00	12.00	317.20	0.00	0.00	111.00	0.00	0.00	11.00	0.22
CITY WELL	12/21/1982	E	5.00	12.00	185.00	15.00	231.80	0.00	0.00	130.00	0.00	0.00	13.00	0.80
CITY WELL	09/01/1985	F	5.40	13.00	135.00	15.00	305.00	0.00	0.00	122.00	0.00	0.00	14.00	0.50
CITY WELL	07/24/1994	G	6.54	18.60	184.00	9.80	300.10	0.00	6.25	166.00	2.00	0.00	0.00	0.00
CITY WELL	07/29/1994	H	6.50	18.70	191.00	14.60	300.10	0.00	8.70	168.00	0.00	0.00	0.00	0.00
CITY WELL	09/20/1994	I	8.65	21.25	201.00	0.00	341.60	0.00	3.10	204.00	0.00	0.00	0.00	0.34

Chemical Constituents in Equivalents per Million

Sample	Date	Symbol	Ca	Mg	Na	K	HCO3	CO3	SO4	Cl	NO3	PO4	Si	Fe	SAR
CITY WELL	09/05/1975	A	0.25	1.32	5.92	0.00	4.70	0.00	0.27	2.88	0.00	0.32	0.00	0.01	6.69
CITY WELL	01/20/1978	B	0.60	1.15	5.26	0.36	5.00	0.00	0.08	3.67	0.00	0.00	0.00	0.00	5.63
CITY WELL	09/05/1979	C	0.31	1.31	6.00	0.36	4.60	0.00	0.00	4.74	0.02	0.00	0.00	0.01	6.68
CITY WELL	05/22/1981	D	0.26	0.99	4.35	0.31	5.20	0.00	0.00	3.13	0.00	0.00	0.00	0.01	5.51
CITY WELL	12/21/1982	E	0.25	0.99	8.05	0.38	3.80	0.00	0.00	3.67	0.00	0.00	0.00	0.03	10.23
CITY WELL	09/01/1985	F	0.27	1.07	5.87	0.38	5.00	0.00	0.00	3.44	0.00	0.00	0.00	0.02	7.18
CITY WELL	07/24/1994	G	0.33	1.53	8.00	0.25	4.92	0.00	0.13	4.68	0.03	0.00	0.00	0.00	8.31
CITY WELL	07/29/1994	H	0.32	1.54	8.31	0.37	4.92	0.00	0.18	4.74	0.00	0.00	0.00	0.00	8.61
CITY WELL	09/20/1994	I	0.43	1.75	8.74	0.00	5.60	0.00	0.06	5.75	0.00	0.00	0.00	0.01	8.38

Percent Reacting Values

Sample	Date	Symbol	%Ca	%Mg	%(Na+K)	%Cl	%SO4	%HCO3	TDS,mg/l	%error
CITY WELL	09/05/1975	A	3.33	17.59	79.07	35.24	3.31	61.45	423.41	4.39
CITY WELL	01/20/1978	B	8.12	15.62	76.26	41.91	0.95	57.13	445.00	8.55
CITY WELL	09/05/1979	C	3.88	16.40	79.72	50.84	0.00	49.16	481.27	7.96
CITY WELL	05/22/1981	D	4.40	16.72	78.88	37.59	0.00	62.41	407.39	17.05
CITY WELL	12/21/1982	E	2.58	10.21	87.21	49.12	0.00	50.88	474.78	12.85
CITY WELL	09/01/1985	F	3.55	14.08	82.37	40.77	0.00	59.23	454.87	5.27
CITY WELL	07/24/1994	G	3.23	15.13	81.64	48.29	1.33	50.38	540.75	1.75
CITY WELL	07/29/1994	H	3.08	14.59	82.34	48.17	1.84	49.99	555.06	3.46
CITY WELL	09/20/1994	I	3.95	16.00	80.05	50.40	0.57	49.03	606.30	2.22

FIGURE 10

HC-Gram
Title: CITY WELL, BIA WELL, AND KINIA RIVER, HIGH TIDE
03-Mar-1995
09:32:16.39

Chemical Constituents in ppm

Sample / Ca	Date / Mg	Symbol / Na	K	HCO3	CO3	SO4	Cl	NO3	PO4	Si	Fe
CITY WELL	07/29/1994	A									
6.50	18.70	191.00	14.60	300.10	0.00	8.70	168.00	0.00	0.00	0.00	0.00
KINIA RIVER	08/02/1994	C									
145.00	464.00	1100.00	187.00	69.30	0.00	374.00	3290.00	0.00	0.00	0.00	0.00
BIA WELL	08/01/1994	B									
26.30	54.80	310.00	28.00	433.70	0.00	12.10	482.00	0.00	0.00	0.00	0.00

Title: CITY WELL, BIA WELL, AND KINIA RIVER, HIGH TIDE
03-Mar-1995
09:32:16.50

Chemical Constituents in Equivalents per Million

Sample / Ca	Date / Mg	Symbol / Na	K	HCO3	CO3	SO4	Cl	NO3	PO4	Si	Fe	SAR
CITY WELL	07/29/1994	A										
0.32	1.54	8.31	0.37	4.92	0.00	0.18	4.74	0.00	0.00	0.00	0.00	8.61
KINIA RIVER	08/02/1994	C										
7.24	38.17	47.85	4.78	1.14	0.00	7.79	92.81	0.00	0.00	0.00	0.00	10.04
BIA WELL	08/01/1994	B										
1.31	4.51	13.49	0.72	7.11	0.00	0.25	13.60	0.00	0.00	0.00	0.00	7.90

Title: CITY WELL, BIA WELL, AND KINIA RIVER, HIGH TIDE
03-Mar-1995
09:32:16.61

Percent Reacting Values

Sample	Date	Symbol	%Ca	%Mg	%(Na+K)	%Cl	%SO4	%HCO3	TDS,mg/l	%error
CITY WELL	07/29/1994	A	3.08	14.59	82.34	48.17	1.84	49.99	555.06	3.46
KINIA RIVER	08/02/1994	C	7.38	38.93	53.69	91.23	7.65	1.12	5594.07	1.85
BIA WELL	08/01/1994	B	6.55	22.52	70.93	64.88	1.20	33.92	1126.45	2.28

NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE FAIRBANKS, ALASKA 99701 (907) 456-3116 • FAX 456-3125
2505 FAIRBANKS STREET ANCHORAGE, ALASKA 99503 (907) 277-8378 • FAX 274-9645

Alaska Dept. of Environmental Conservation
Village Safe Water/Construction Grants
3601 C Street; Suite 310
Anchorage AK 99503

Attn: -

Report Date: 10/19/94

Date Arrived: 09/22/94
Date Sampled: 09/20/94
Time Sampled: 1423
Collected By: -

MDL = Method Detection Limit

Our Lab #: F142719
Location/Project: (A134249)
Your Sample ID: Cherfornak City Water
Sample Matrix: Water
Comments:

* Flag Definitions
B = Below Regulatory Min.
H = Above Regulatory Max.

Lab Number	Method	Parameter	Units	Results	MDL	Date Prepared	Date Analy
F142719	EPA 200.7	Aluminum	mg/l	<MDL	0.055		09/29/
	EPA 200.7	Barium	mg/l	0.042	0.006		09/29/
	EPA 200.7	Beryllium	mg/l	0.0006	0.0004		09/29/
	EPA 200.7	Calcium	mg/l	8.65	0.017		09/27/
	EPA 200.7	Copper	mg/l	0.015	0.005		09/22/
	EPA 200.7	Hardness as CaCO3	mg/l	109	0.1		09/27/
	EPA 200.7	Iron	mg/l	0.342 H	0.01		09/28/
	EPA 200.7	Manganese	mg/l	0.033	0.005		09/28/
	EPA 200.7	Nickel	mg/l	<MDL	0.025		09/28/
	EPA 200.7	Sodium	mg/l	201	0.7		10/04/
	EPA 200.7	Zinc	mg/l	<MDL	0.01		09/28/
	EPA 204.2	Antimony	mg/l	<MDL	0.003		09/29/
	EPA 206.2	Arsenic	mg/l	<MDL	0.003		09/27/
	EPA 213.2	Cadmium	mg/l	<MDL	0.0001		10/11/
	EPA 218.2	Chromium	mg/l	0.002	0.001		10/05/
	EPA 239.2	Lead	mg/l	0.004	0.002		09/30/
	EPA 245.1	Mercury	mg/l	<MDL	0.0002		10/06/
	EPA 270.2	Selenium	mg/l	<MDL	0.002		09/28/
	EPA 272.2	Silver	mg/l	<MDL	0.0001		10/03/

Patricia A Woody

Reported By: Patricia A. Woody
Senior Chemist

NORTHERN TESTING LABORATORIES, INC.
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Lab Number	Method	Parameter	Units	Results	MDL	Date Prepared	Date Analy
F142719	EPA 279.2	Thallium	mg/l	<MDL	0.001	09/27/94	09/30
	EPA 325.3	Chloride	mg/l	204	1		10/06
	EPA 335.2	Total Cyanide	mg/l	<MDL	0.01		10/07
	EPA 340.2	Fluoride	mg/l	0.37	0.02		09/22
	EPA 376.1	Sulfate	mg/l	3.10	1		10/14
	EPA 425.1	Foaming Agents	mg/l	<MDL	0.1		09/22

Patricia A. Woody

Reported By: Patricia A. Woody
Senior Chemist

NORTHERN TESTING LABORATORIES, INC.

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2505 FAIRBANKS STREET ANCHORAGE, ALASKA 99503 (907) 277-8378 • FAX 274-9645

Village Safewater
3601 C Street, Suite 310
Anchorage AK 99503

Attn: -

Report Date: 10/12/94
Date Arrived: 09/21/94
Date Sampled: 09/20/94
Time Sampled: 1423
Collected By: -

* Definitions *
B = Below Regulatory Min.
H = Above Regulatory Max.
E = Estimated Value
M = Matrix Interference
D = Lost to Dilution
MDL = Method Detection Limit

Our Lab #: A134249
Location/Project: -
Your Sample ID: Chefornak City Water
Sample Matrix: Water
Comments:

Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analyz
A134249	502.2/524.2	Benzene	ug/l	<MDL		0.20		09/23/
		Bromobenzene	ug/l	<MDL		0.20		
		Bromochloromethane	ug/l	<MDL		0.30		
		Bromodichloromethane	ug/l	<MDL		0.20		
		Bromoform	ug/l	<MDL		0.50		
		Bromomethane	ug/l	<MDL		0.50		
		n-Butylbenzene	ug/l	<MDL		0.20		
		s-Butylbenzene	ug/l	<MDL		0.20		
		tert-Butylbenzene	ug/l	<MDL		0.20		
		Carbon Tetrachloride	ug/l	<MDL		0.20		
		Chlorobenzene	ug/l	<MDL		0.20		
		Dibromochloromethane	ug/l	<MDL		0.20		
		Chloroethane	ug/l	<MDL		0.50		
		Chloroform	ug/l	<MDL		0.20		
		Chloromethane	ug/l	<MDL		0.50		
		o-Chlorotoluene	ug/l	<MDL		0.20		
		p-Chlorotoluene	ug/l	<MDL		0.20		
		1,2-Dibromo-3-Chloropropane	ug/l	<MDL		0.50		
		Dibromomethane	ug/l	<MDL		0.20		
		1,4-Dichlorobenzene	ug/l	<MDL		0.20		
		m-Dichlorobenzene	ug/l	<MDL		0.20		
		o-Dichlorobenzene	ug/l	<MDL		0.20		
		Dichlorodifluoromethane	ug/l	<MDL		0.50		
		1,1-Dichloroethane	ug/l	<MDL		0.20		
		1,2-Dichloroethane	ug/l	<MDL		0.20		
		1,1-Dichloroethylene	ug/l	<MDL		0.20		
		cis-1,2-Dichloroethylene	ug/l	<MDL		0.20		
		trans-1,2-Dichloroethylene	ug/l	<MDL		0.20		
		Methylene Chloride	ug/l	<MDL		0.50		
		1,2-Dichloropropane	ug/l	<MDL		0.20		
		1,3-Dichloropropane	ug/l	<MDL		0.20		

Reported By: Anthony J. Lange
Chemistry Supervisor

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Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analyz
A134249	502.2/524.2	2,2-Dichloropropane	ug/l	<MDL		0.20		09/23/
		1,1-Dichloropropene	ug/l	<MDL		0.20		
		1,3-Dichloropropene	ug/l	<MDL		0.20		
		Ethylbenzene	ug/l	<MDL		0.20		
		1,2-Dibromoethane	ug/l	<MDL		0.20		
		Fluorotrichloromethane	ug/l	<MDL		0.20		
		Hexachlorobutadiene	ug/l	<MDL		0.20		
		Isopropylbenzene	ug/l	<MDL		0.20		
		p-Isopropyltoluene	ug/l	<MDL		0.20		
		Naphthalene	ug/l	<MDL		0.20		
		n-Propylbenzene	ug/l	<MDL		0.20		
		Styrene	ug/l	<MDL		0.20		
		1,1,1,2-Tetrachloroethane	ug/l	<MDL		0.20		
		1,1,2,2-Tetrachloroethane	ug/l	<MDL		0.20		
		Tetrachloroethylene	ug/l	<MDL		0.20		
		Total Trihalomethane	ug/l	<MDL		1.00		
		Toluene	ug/l	<MDL		0.30		
		1,2,3-Trichlorobenzene	ug/l	<MDL		0.20		
		1,2,4-Trichlorobenzene	ug/l	<MDL		0.20		
		1,1,1-Trichloroethane	ug/l	<MDL		0.20		
		1,1,2-Trichloroethane	ug/l	<MDL		0.20		
		Trichloroethylene	ug/l	<MDL		0.20		
		1,2,3-Trichloropropane	ug/l	<MDL		0.20		
		1,2,4-Trimethylbenzene	ug/l	<MDL		0.20		
		1,3,5-Trimethylbenzene	ug/l	<MDL		0.20		
		Vinyl Chloride	ug/l	<MDL		0.50		
		m,p-Xylenes	ug/l	<MDL		0.20		
		o-Xylene	ug/l	<MDL		0.20		
		Surrogate Recovery	%	106				
A134249	EPA 110.2	Color, Apparent	Unit	300		5		09/22/9

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Chemistry Supervisor

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Lab Number	Method	Parameter	Units	Result	*	MDL	Date Prepared	Date Analy
A134249	EPA 120.1	Conductance	umhos	1342		1		09/21
A134249	EPA 150.1	pH	Unit	8.3				09/21,
A134249	EPA 160.1	Total Dissolved Solids	mg/l	610		1		09/23/
A134249	EPA 180.1	Turbidity	NTU	0.3		0.2		09/21/
A134249	EPA 310.1	Alkalinity as CaCO3	mg/l	280		1		09/22/
A134249	EPA 353.3	Nitrate-N	mg/l	<MDL		0.10		09/21/
A134249	EPA 354.1	Nitrite-N	mg/l	<MDL		0.020		09/21/
A134249	Sim.Dist.	Bromoform	ug/l	<MDL		0.50		10/05/
		Bromodichloromethane	ug/l	<MDL		0.20		
		Chloroform	ug/l	<MDL		0.20		
		Dibromochloromethane	ug/l	<MDL		0.20		
		Surrogate Recovery	%	98				
		Total Potential Trihalomethanes	ug/l	<MDL		1.00		
A134249	SM 203	Langelier Index		0.04				10/10/
A134249	SM 207	Odor	TON	<MDL		1		09/22/

Reported By: Anthony J. Lange
Chemistry Supervisor

15.2°C, pH from 6.7 to 7.7, and conductivity from 1,578 to 20,381 μS/cm. Iron levels varied from 0.8 to 1.8 mg/l, and nitrate levels were nominal, from 0 to 0.2 mg/l. Hardness ranged from 132 to 2115 mg/l, and alkalinities from 24 to 56 mg/l. Chloride levels were near or beyond measurable range, varying from 485 to 610 mg/l.

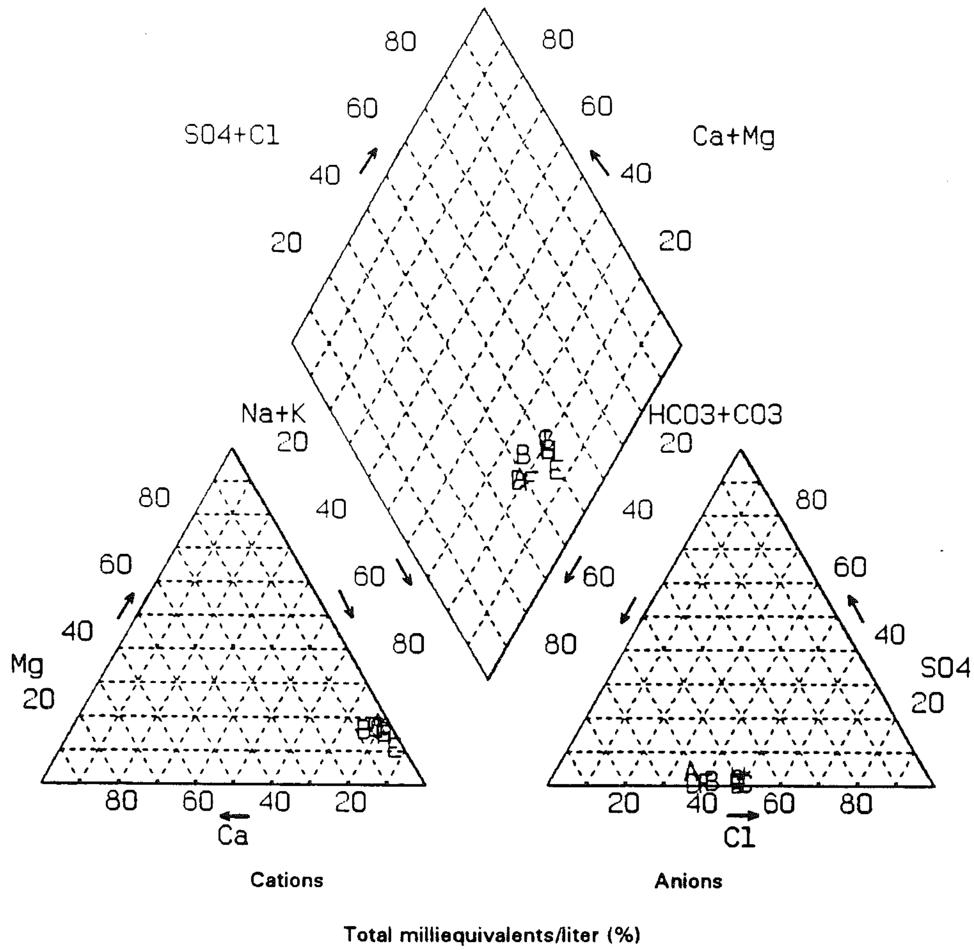
Major Inorganic Constituents

Major inorganic constituents in ground water include dissolved cations (positively charged ions) and anions (negatively charged ions) that generally occur in concentrations greater than a few milligrams per liter. They are used to characterize water samples, group similar samples, and determine mixing trends. Major cations are calcium, magnesium, sodium, and potassium. Major anions are bicarbonate (a major part of alkalinity), chloride, and sulfate. These are plotted on a trilinear diagram which is a graphical method used to compare water samples and show their chemical composition. A trilinear diagram contains three fields for plotting major ion values--two equilateral triangles at the lower left and lower right corners of the diagram for cations and anions, respectively, and a diamond-shaped field between the triangles which indicates the relative composition in terms of cation-anion pairs. The proportions of cations and anions (in percentage of total milliequivalents per liter) are plotted as points in each of the lower triangles. The points are then extended into the central plotting field by projection. The intersection of these projections represents the composition of the water (Hem, 1985). The trilinear plots are useful for visually determining groupings of water samples, or mixing trends between different samples. Units of milliequivalents per liter (meq/l) are used based on the concentration of each major ion (in mg/l), the ion's electrical charge, and the reciprocal of the ion's molecular weight. When expressed in milliequivalents per liter, the sum of the cation values equals the sum of the anion values.

City Well

Historical data supplied by VSW indicates that the chemical composition of the city well has been very consistent (Figure 8). The water type is sodium-bicarbonate to sodium-chloride-bicarbonate. No temporal variation in chemical composition is observed over the 19 years.

A slight upward trend in calculated TDS concentration is observed when 1994 data are compared to historical (1975 to 1985) data (Appendix B). The average TDS concentration is 567 mg/l in 1994, compared to 448 mg/l between 1975 and 1985. The TDS concentrations in 1994 exceed the secondary maximum contaminant level (MCL) of 500 mg/l listed in the Alaska Drinking Water Regulations (ADEC, 1994).



EXPLANATION

Symbol	Date	Water type
A	09-05-75	sodium bicarbonate
B	01-20-78	sodium bicarbonate
C	09-05-79	sodium chloride bicarbonate
D	05-22-81	sodium bicarbonate
E	12-21-82	sodium chloride bicarbonate
F	09-01-85	sodium bicarbonate
G	07-24-94	sodium chloride bicarbonate
H	07-29-94	sodium chloride bicarbonate
I	09-20-94	sodium chloride bicarbonate

Figure 8. Trilinear diagram showing water-type classification of water collected from the city well in Chefornak, Alaska.

Ground water from the WW-2 well had a turbidity of 5.8 NTU. Trace metal and minor element concentrations were low. Only iron had a concentration which exceeded the MCL (1.8 mg/l). Fecal coliform bacteria colonies were undetected. The trans-1,2-Dichloroethylene concentration (0.2 mg/l) exceeded the MCL of 0.1 mg/l (ADEC, 1994). Toluene was detected at a concentration of 0.67 mg/l; the MCL for toluene is 1 mg/l (ADEC, 1994). Neither compound was detected in the travel blank sample, but their presence may be due to the recent drilling. The occurrence of the volatile organic compounds is unconfirmed because only one sample was taken.

The WW-3 well had water of low turbidity (0.7 NTU) and high color (100 color units). Most trace metal and minor element concentrations were low. The iron concentration (0.59 mg/l) and manganese concentration (0.05 mg/l) exceeded MCLs. Fecal coliform bacteria colonies were undetected. Chloroform was detected in WW-3. The origin of the chloroform is unknown and is unconfirmed because only one sample was taken. A possible source could be any drilling equipment used down hole prior to sampling that was disinfected with bleach.

SUMMARY

The increase in head with depth is evidence of an upward vertical gradient within the aquifer, and that Chefornak lies within a discharge zone of the regional flow system. If permafrost is absent beneath the river channel, there is probably a component of ground water discharge from the aquifer to the Kinia River during non-pumping conditions. With increased distance away from the river, the bottom of the permafrost layer descends. Within the thaw bulb of the river, the brackish water interface was located at 140 depth (-120 ft elevation). WW-5, located 50 feet from the river encountered water in the borehole at 27 feet deep. To avoid problems associated with proximity to the river or the descending base of permafrost, exploration was constrained to a relatively narrow band of about 80 to 130 feet from the river.

The new wells have low yields, and large drawdowns. Predictions are that if well production heads are drawn much below river level, they may be subject to infiltration from the river (HDR, 1992). Susceptibility varies directly with the amount of drawdown, and inversely with the square of the distance from the river. It has also been predicted from simple models that if production water levels are drawn below 2.5 to 5 feet above sea level, they will be subject to brackish water upconing (HDR, 1992).

To provide a safe yield for producing wells, average production drawdowns should be no more than four or five feet for WW-2, WW-3, the City, and BIA wells. Since drawdowns vary directly with pumping rate, WW-2 and WW-3 should be pumped at approximately one tenth of their tested capacity, or 0.4 and 0.4-0.5 gpm. Similarly, to prevent further degradation, the BIA well should be attenuated to 11.2 gpm x (4 ft/32 ft) = 1.4 gpm, and the City well to 9 gpm x (4 ft/11.6 ft) = 3.1 gpm. The recommended long-term solution to ground water development is to rely on a sufficient number of wells to meet the system needs (pumped at low rates and monitored to prevent exceedance of allowable drawdowns or conductivity levels). Based on the City, BIA, WW-2, and WW-3 wells, and for estimation purposes only, the upper limit of expected safe well yield is one gallon per minute.

Calculated aquifer transmissivities from WW-2, WW-3, and BIA pumping test range from 19.4 to 1,180 gpd/ft, with a probable range of 20 to 200 gpd/ft. Wells were too far apart to note drawdown effects in observation wells preventing the calculation of storativity. An estimated aquifer storativity of 0.0005 was used in a Theis equation to estimate a radius of zero influence of 100 to 200 feet. Well spacing should be based on pump test results to minimize construction costs from spacing wells too far apart.

Thickness of the aquifer below the permafrost near the river may be as much as 90 feet, but the brackish water interface encountered in WW-1 and WW-2 at the -120 foot elevation constrains the useable thickness of the aquifer (Table 1). The bottom of the production zone should remain at least 20 feet above the brackish zone to minimize possible upconing. The calculated mean useable aquifer thickness taking into account the separation distance of 20 feet above the brackish water is 32.5 feet. Until more data are available, yield projections based on aquifer geometry should use 32.5 feet.

The horizontal gradient is very low, and difficult to assess. Water levels in Figure 1 suggest a horizontal gradient of 0.6 ft per 770 feet but differing water levels in wells finished at different depths are probably due more to vertical gradients than piezometric gradients.

The production aquifer consists of unfrozen fine sands containing pea gravel, shells, mica, and wood. These deposits are evidence of paleoenvironments of beaches or littoral zones of high energy activity. The shells, mica, and wood can decrease the water-yielding capacity by plugging well screens.

During pumping conditions, if the drawdown is below river level, recharge is likely to occur from a combination of infiltration from the Kinia River and from regional ground water flow. If drawdown does not go below the river level, recharge should be from the regional ground water system. In wells near the river, long-term sustained drawdowns below Kinia River elevations could cause degradation of water quality. The critical component for prevention of river water infiltration and upconing is drawdown. The drawdown should be kept above the river level to maintain ground water flow to the river and minimize upconing.

The working model used in exploring for ground water was to envision the aquifer as a thawed prism underlying and immediately adjacent to the Kinia river. Drilling experiences and water quality trends in wells show that these restrictions are narrower than originally assumed. The geometry of the developable freshwater aquifer is constrained by the potential for river water infiltration, the underlying brackish water interface (which prevents wells from being finished below 120 feet), and the descending base of the permafrost.

Based on observed and potential infiltration from the river and the depth to the bottom of permafrost, groundwater exploration should be conducted in a band 80 to 120 feet from the riverbank.

The ground waters obtained from the WW-2 and WW-3 wells contain detectable concentrations of volatile organic compounds. Based on inorganic constituent concentrations, ground waters from the WW-2 and WW-3 wells are acceptable for domestic use. However, potability depends on further volatile organic compound testing.

RECOMMENDATIONS

Collect TDS data for the city well, especially during early September for historical data comparisons, to determine whether the TDS concentration is trending upward.

Analyze ground water from WW-2 and WW-3 for volatile organic compounds. Replicate samples with good quality control procedures are required to confirm the presence of toluene, trans-1,2-Dichloroethylene, and chloroform.

Sample deep brackish water (below approximately -120 feet) to assess upconing potential.

Well drilling showed that permafrost depth is highly variable. If future drilling is desired, geophysical surveys should be run to help identify target sites. A geophysical survey may be able to characterize the water quality in the aquifer, delineate the bottom of the permafrost, and identify the brackish water interface depths.

If further ground water exploration is desired, another alternative would be to efficiently drill a relatively large number of holes. An air rotary rig could economically accomplish a drilling project in a fraction of the time required by cable tool methods. If a drill rig with directional capabilities were used, long horizontal collection galleries may also present a practical solution. Rotary drilling combined with an electromagnetic survey would probably make for the most accurate and cost-effective approach to ground water exploration.

Further well testing should employ at least one observation well located within 20 to 30 feet of the pumped well. A second observation well located within 50 feet in a different radial direction away from the pumped well would give a more accurate picture of drawdown propagation, and variations in transmissivity within the aquifer. This will allow calculation of storativity values, and construction of a distance-drawdown plot to facilitate optimum well spacing. Pumping tests may not indicate the presence of aquifer boundaries which may affect the wells after months of pumping.

We have appreciated this opportunity to be of service, and hope our work will help in your search for an adequate water source for the city. If you have further questions or we can be of further service, please let us know.

Sincerely,

Alaska DNR, Division of Mining and Water Management

Roger Allely

Roger Allely
Hydrologist

Attachments