A Review of Ground Water Quality in the Dog Creek Road Community

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Introduction

Ground water is an essential and vital resource for many residents of British Columbia and provides many households with water for drinking and washing. As ground water is not readily visible, it remains a hidden resource whose value is not well understood or appreciated. In recent years, events affecting ground water quality have heightened public awareness and concern about the importance and vulnerability of the resource.

Ground water exists almost everywhere within the ground, but some areas contain more water than others. The water table is the level below which all spaces in the soil are filled with water. The region below the water table is called the saturated zone. An aquifer is a saturated zone that produces useful quantities of water when tapped by a well (see Figure 1).

Ground water quality is influenced by natural factors such as local geology, climate and hydrology. Ground water quality can also be affected by human activities. Any addition of undesirable substances to ground water caused by human activities is considered to be contamination. Potential sources of contamination include:

- Fertilizers and pesticides on agricultural land
- Sewage disposal
- Livestock wastes
- Fuel storage tanks
- Runoff of salt and chemicals from roads and highways.

Soil particles slow and reduce the transport of most of these contaminants, which is why ground water is generally considered a safer drinking water source than surface water.

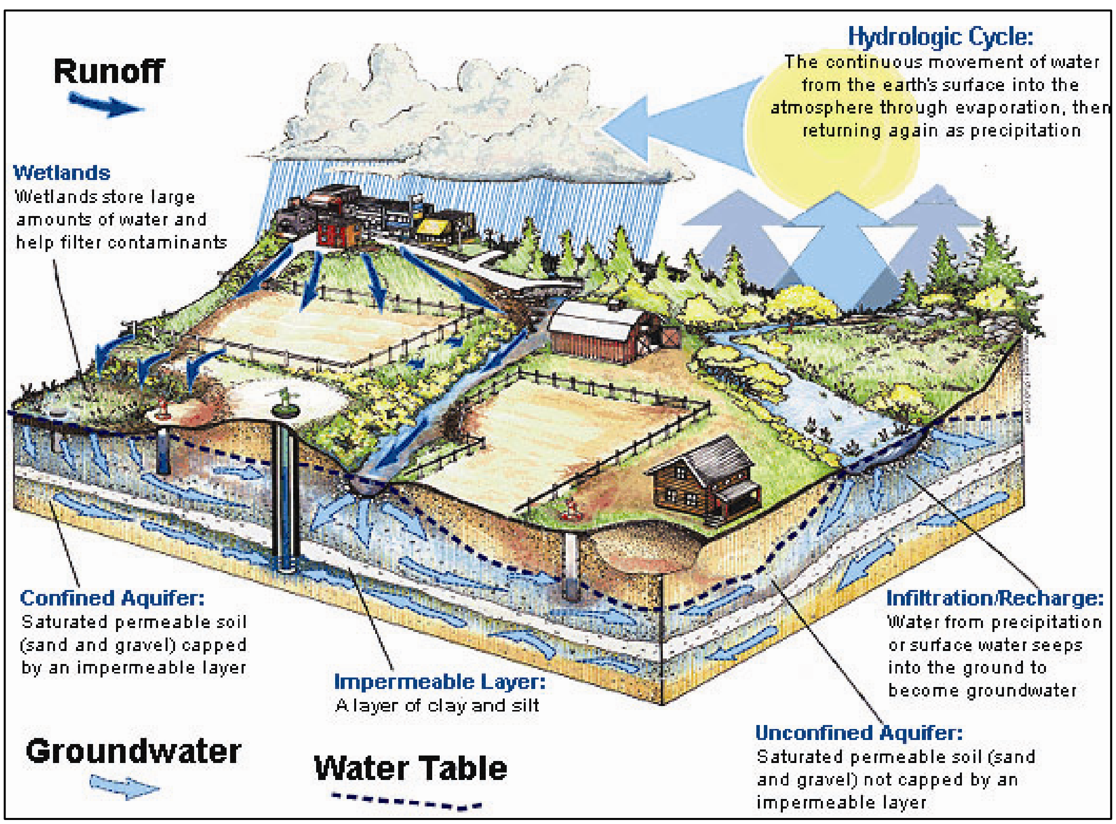

Figure 1 – Schematic diagram of aquifer and well concepts by Greg Linquist – Quist Studio

Study Objectives

In 1980, the province constructed an observation well beside Dog Creek Road near Williams Lake, to monitor ground water levels and quality in the Dog Creek Road community. At the time of construction, the ground water from the well was already elevated in nitrate-nitrogen indicating that ground water quality had been impacted by human activities. The Ministry of Environment's most recent sampling in June 2005 indicated that the nitrate-nitrogen concentration in the observation well was still high and continued to reflect a human impact.

In late 2005 and in 2006, the Ministry of Environment expanded the ground water quality monitoring to include a selection of privately owned wells. The objectives of the broader based sampling program were to:

- Test for the presence of human related ground water contaminants throughout the community;
- Compare ground water quality to the Guidelines for Canadian Drinking Water Quality;
- Assess what percentage of the sampled wells demonstrated poor water quality due to human impact; and
- Report back to the community and local government on the ground water quality, to assist these groups in long term ground water protection planning.

The Study Area

The Dog Creek Road community is a residential area along Dog Creek Road south of Williams Lake. The community is outside the City of Williams Lake municipal boundary and within the jurisdiction of the Cariboo Regional District. Development in the study area includes approximately 300 residential lots, four mobile home parks, an elementary school, a convenience store and a pub.

Land use in the developed portion of the community is primarily residential. An inactive gravel pit is located within the community near Denny Road. The upland/southern portion of the study area includes undeveloped forest, an active gravel mining operation and an automobile racetrack. The study area is outlined on Figure 2 and Figure 3.

The study area is not serviced by a community water or sewer system. The community relies on ground water for its water supply. The mobile home parks have their own water systems, but the residential lots are primarily on individual wells. The method of sewage disposal in the community is septic tank treatment with ground disposal.

Local Geology and Ground Water Occurrence

The Dog Creek Road area experienced two periods of glaciation and is overlain by glacial drift (unconsolidated glacial deposits of clay, silt, sand and gravel). The glacial drift varies in thickness, from approximately 80 m thick to nothing where bedrock is exposed at the ground surface. The glacial drift is approximately 60 m thick at the location of the provincial observation well near the northwest corner of Kendall Acres Mobile Home Park.

Sand and gravel glacial outwash was deposited from Bond Lake northeasterly to Dog Creek Road. The sand and gravel is overlain by glacial till[1] in varying thicknesses. The outwash deposits have been mined for sand and gravel at the former Denny gravel pit and the Centennial gravel pit near Bond Lake. The sand and gravel glacial outwash is also a productive aquifer and a source of ground water for wells drilled in the lower Bond Road and Denny Road area.

Further west in the Gibbon Road area and southeast in the Gun-a-Noot Trail and Mussel Place areas, the glacial drift is primarily comprised of silt and clay till. These soil types do not yield much ground water and the majority of wells in these areas are drilled into the underlying bedrock.

Geological Survey of Canada bedrock geology mapping[2] indicates that bedrock in the southern area of Dog Creek consists of basalt. Bedrock in the west and southwestern portion of Dog Creek and Chimneys Valley consists of marine sedimentary rock including chert, limestone and sandstone. The provincial observation well on Dog Creek Road intercepted fractured sandstone at 58 m below ground. The sandstone at the well site is a very productive bedrock aquifer.

The primary source of groundwater recharge to the aquifers beneath the study area is infiltration from precipitation. The regional direction of ground water flow is northward towards Williams Lake. Localized recharge can occur from precipitation in the glacial outwash areas and seepage through the base of upland lakes. The lower part of Dog Creek is a ground water discharge zone where ground water is rising up to the ground surface. Slope failures near the intersection of Dog Creek Road and Highway 20 and flowing wells in this same

[1] Till - an unsorted mixture of clay, silt, sand and gravel
[2] Tipper, H.W., Map 12-1959 Geology Quesnel Cariboo District. British Columbia. GSC, Ottawa Canada, 1959

area, are indications of this ground water discharge zone.

In 1994, the B.C. government established an aquifer classification system to inventory and prioritize aquifers for planning, management and protection of the Province's ground water resource. This system classifies aquifers based on development, vulnerability to contamination and importance of the aquifer.

The level of aquifer development is classified as I, II or III. A "I" classification means the aquifer is highly developed relative to the amount of water available in the aquifer, At the other end of the scale, a "III" means there is not a lot of use of the aquifer relative to the amount of ground water available.

Vulnerability ratings are A, B or C. An "A" rating means the aquifer is unconfined and highly vulnerable to surface sources of contamination. A "C" rating means the aquifer is the least vulnerable to surface contamination. A "C" rated aquifer has a cover layer of low permeability sediments such as till, clay and silt overlying the aquifer that protect it from surface sources of contamination.

The two provincially mapped aquifers in the study area are illustrated on Figures 2 and 3. The sand and gravel (glacial outwash) aquifer in the vicinity of Denny Road is aquifer # 152 and has a IC rating. The area of aquifer # 152 is illustrated by orange diagonal hatching. The aquifer underlying the remainder of the study area is aquifer # 148 and is a bedrock aquifer with a IIIC rating. This aquifer is illustrated by blue diagonal hatching.

Aquifer No 148 (IIIC) Fast Facts

- Bedrock aquifer.
- Aquifer is overlain by low permeable glacial till ranging from 20 feet (6 m) to 150 feet (46 m) in thickness.
- Average depth to water table is 69 feet (21 m).
- Average well depth is 171 feet (51 m).
- Average reported well yield is 6 gpm (0.45 L/sec).

Aquifer No 152 (IC) Fast Facts

- Mostly sand and gravel aquifer.
- Aquifer is overlain by low permeable glacial till ranging from 10 feet (3 m) to 70 feet (21 m) in thickness.
- Average depth to water table is 43 feet (13 m).
- Average well depth is 118 feet (36 m).
- Average reported well yield is 8 gpm (0.61 L/sec).

Figure 4 illustrates an unconfined aquifer that does not have a protective soil layer over top of it. Precipitation recharge (and any contaminants) can easily move downwards from the land surface to the water table. This makes an unconfined aquifer vulnerable to contaminants from septic systems or by surface infiltration of rainfall and snow melt percolating into the ground and transporting different substances (such as fertilizers, pesticides, petroleum products, road salt) into the ground water.

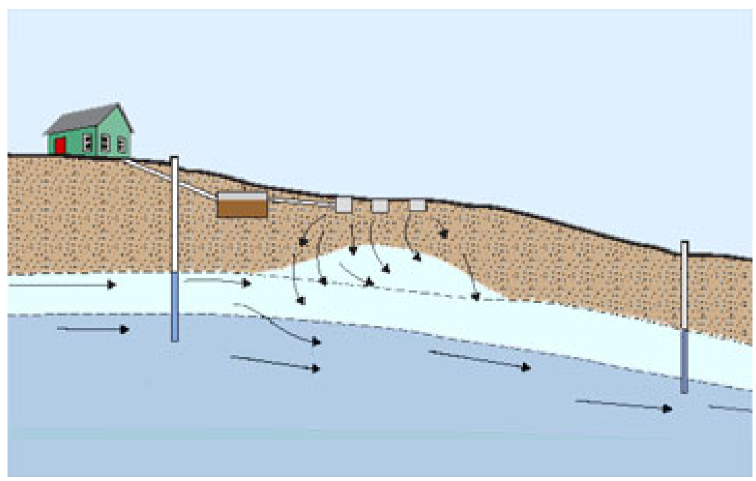

Figure 4 – Diagram showing movement of sewage effluent from a septic system to the underlying water table (from the Consortium of Institutes for Decentralized Wastewater Treatment http://www.onsiteconsortium.org/graphics.cfm)

We need to recognise that although an aquifer may have an overlying protective layer, it is still susceptible to contaminants that can enter the aquifer through abandoned wells, poorly constructed wells, wells located too close to septic fields or fractures in the confining layer.

Human Impact Indicators

Nitrate

Nitrate-nitrogen is a good indicator for contamination by sewage disposal, leaching fertilizer and leaching animal manure and is often considered a first sign of deteriorating ground water quality.

Nitrate is a chemical compound of one part nitrogen and three parts oxygen and is the most common form of nitrogen in water. In water, nitrate has no taste or scent and can only be detected through a chemical test. The nitrate-nitrogen level in most ambient ground water in B.C. is very low, generally much less than 1 mg/L.[3]

What is a safe nitrate level?

Though nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water can be a health concern for several reasons.

1. Nitrate can harm infants by reducing the ability of their blood to transport oxygen.

2. Elevated nitrate is an indication that there may be other sewage related contaminants present that are not routinely tested for. These ground water contaminants could include pathogens, viruses, pharmaceuticals, household chemicals, cleaners and any other chemicals that flushed into a septic system. Ground water contaminants could be ingested by drinking the water or inhaled during showering.

The Ministry of Environment considers a nitrate concentration of 3.0 mg/L or higher to be an indication of human impact. The Canadian Drinking Water Guideline (CDWG) maximum acceptable concentration for nitrate-nitrogen is 10 mg/L.[4] Boiling water does not remove nitrate. Pitcher type filtration units do not remove nitrate. Treatment methods such as distillation, anion exchange and reverse osmosis are effective methods of nitrate removal.

Chloride

Chloride is also a good indicator for salt and sewage contamination. Sources of chloride include road salt, water softener discharges and sewage effluent. The Canadian Drinking Water Guideline for chloride is 250 mg/L. This guideline is an aesthetic objective rather than a heath related guideline. A high chloride concentration gives the ground water an undesirable taste. Chloride is the most abundant anion in the body and is well regulated by the body. Health Canada reports that no evidence has been found that ingestion of chloride is harmful to humans.

How were sites selected?

Twenty-nine sites were sampled in the Dog Creek Road area. The sites included private residential wells, community (mobile home parks and elementary school) water wells, a ground water quality monitoring well, the provincial observation well and Bond Lake. Bond Lake was sampled to investigate the influence of the lake water on the ground water chemistry.

The study area and sampling sites are shown on Figure 2 and Figure 3. Wells were selected based on:

- Spacing to provide reasonable coverage of the study area;
- Proximity to likely sources of contamination;
- Availability of raw, untreated water; and,
- Accessibility.

How were samples collected?

Untreated water samples were collected in plastic bottles at outside faucets and/or indoor taps. Taps were flushed for several minutes prior to collecting samples to ensure the samples did not contain substances that may leach from plumbing systems. Water samples from monitoring wells were collected with sanitary hand bailers. Samples were then placed in coolers with ice and shipped to Maxxam Analytics Inc. Selected wells were sampled in triplicate for QAQC.

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[3] B.C. MOE, Well Stewardship Information Series, *Nitrate in Ground water*, September 2002

[4] Health Canada. 2003. Summary of Guidelines for Canadian Drinking Water Quality.

What were the sampling results?

The results for the entire study are summarized in Table 1. Water wells were sampled in November 2005 and again in spring or summer 2006. Each water sample was analyzed for general parameters, nitrogen compounds, anions and total metals.

General Parameters: Water samples were tested for parameters that are useful to characterize general properties including: pH, total dissolved solids (TDS), turbidity, alkalinity and hardness. The results indicated that the ground water was generally extremely hard and mineralized. TDS ranged from 360 mg/L to 2600 mg/L and the average TDS concentration of 994 mg/L exceeded the CDWG aesthetic objective of 500 mg/L.

Turbidity was also commonly exceeded with twenty of the twenty-five wells sampled in November 2005 exceeding the CDWG of 1 NTU. In 2006, fifteen of the twenty-eight wells sampled exceeded CDWG for turbidity. Elevated turbidity can be an indication of poor well design, construction (well development), maintenance or operation.

Nitrogen: Water samples were tested for different chemical forms of nitrogen including ammonia, nitrate and nitrite. Nitrate-nitrogen is the most common form of nitrogen in ground water. The nitrate-nitrogen concentrations ranged from 0.002 to 12.70 mg/L with an average concentration of 3.9 mg/L and a median concentration of 1.8 mg/L. Ground water samples from five wells were at or above the CDGW of 10 mg/L. Fourteen of the twenty-eight wells sampled, had nitrate-nitrogen concentrations that reflected human impact (nitrate-nitrogen of 3 mg/L or more).

Comparing sand and gravel wells to bedrock wells in the developed area of the community, ten of the thirteen (77%) sand and gravel wells had nitrate-nitrogen concentrations > 3 mg/L with three of the wells exceeding the CDWG of 10 mg/L. Four of the thirteen (30%) bedrock wells sampled had nitrate-nitrogen concentrations > 3 mg/L with two of the wells at or above the CDWG of 10 mg/L.

Background concentrations for nitrate-nitrogen are represented by ground water samples from the upland area of Bond Lake and the Thunder Mountain Speedway (Figure 3). Nitrate-nitrogen concentrations in five ground water samples from this area ranged from 0.08 mg/L to 0.80 mg/L and averaged 0.47 mg/L. The nitrate-nitrogen concentration in a surface water sample from Bond Lake was 0.009 mg/L.

The sampling results for nitrate-nitrogen and chloride are plotted as coloured circles on Figure 2 and Figure 3. Figure 2 provides data from November 2005 sampling and Figure 3 provides data from sampling in spring and summer 2006. The data is plotted in four sizes of circles with increasing concentrations represented by an increase in the size of the circle. Nitrate-nitrogen concentrations exceeding the CDWG of 10 mg/l are also coloured red and chloride concentrations exceeding the CDWG of 250 mg/L are coloured yellow.

Dissolved Anions: Chloride concentrations ranged from 2.6 mg/L to 487 mg/L, with seven of twenty-eight (25%) well sites exceeding the CDWG aesthetic objective of 250 mg/L. Chloride concentrations exceeded the CDWG in five bedrock wells and two sand and gravel wells.

The well immediately north of Bond Lake was sampled four times in spring and summer 2006, as the first ground water sample contained an unexpectedly high concentration of chloride (292 mg/L) for a background area. The concentration of chloride in the three follow-up samples ranged from 5.0 mg/L to 5.8 mg/L. The plotted circle for this well represents the average chloride concentration of 77 mg/L. The chloride concentrations in two surface water samples from Bond Lake were 51 mg/L and 73 mg/L.

Sulphate ranged from 15 mg/L to 866 mg/L with one well sample exceeding the CDWG aesthetic objective of 500 mg/L.

Total Metals: Ground water samples were also tested for total metals. Metals occur naturally in ground water at different concentrations based on the geological properties of the surrounding soil and rocks. Higher concentrations of metals in ground water may occur due to human activities such as mining or industry. In addition, lead and copper are sometimes found in drinking water. These two metals are not usually elevated within the ground water, but get into the water by leaching out of pipes and soldered joints.

Metals concentrations in the ground water samples met the CDWG except for iron, manganese and sodium. Total iron concentrations ranged from 0.001 mg/L to 1.41 mg/L and exceeded the CDWG aesthetic objective of 0.3 mg/L in eight wells. Total manganese concentrations ranged from 0.0001 mg/L to 0.245 mg/L and exceeded the CDWG aesthetic objective of 0.05 mg/L in three wells. Elevated iron and manganese can stain laundry and plumbing fixtures and contribute to poor tasting water. Sodium concentrations ranged from 29 mg/L to 361 mg/L and exceeded the CDWG aesthetic objective of 200 mg/L in nine wells.

What do the sampling results tell us?

We can see that elevated concentrations of nitrate-nitrogen occurred most frequently in the sand and gravel aquifer (Aquifer 152) within and down slope of residential development. Nitrate-nitrogen concentrations in Aquifer 152, are also much higher than in the background area of Bond Lake.

The provincial observation well is also located within Aquifer 152, but is drilled through the upper sand and gravel aquifer and completed (monitoring ground water) in the underlying bedrock aquifer (Aquifer 148). The observation well is also contaminated by nitrogen even though there are protective low permeable layers (glacial till) between the sand and gravel, and the underlying bedrock.

The low permeable layers should prevent surface sources of contaminants from infiltrating the bedrock aquifer. The presence of contamination suggests that there may be additional pathways for contaminants to travels downwards into the bedrock aquifer. These pathways could include abandoned or poorly constructed water wells that intercept shallow septic leachate and transmit the leachate deeper into the aquifer. During the field work, MOE field staff observed nine residential lots with more than one well. At two sites the additional well was operated as a backup well, but at the other sites, the wells had been abandoned.

The Sanitary Regulation requires a minimum separation distance of 30 metres (100 ft) between a septic field and a water well. Ministry staff observed that at least 30% of the wells sampled during the study, were within 30 metres (100 ft) of the onsite or neighbouring septic field.

Nitrate-nitrogen concentrations are plotted against well depth in Figure 5. If contaminants were only entering the aquifer by percolating through the soil, then we would expect to see a decrease in nitrate concentrations with an increase in well depth. We can see from the graph that wells approximately 300 ft (91 m) or deeper had the lowest concentrations of nitrate, but for wells shallower than 300 ft there was no significant pattern or trend of decreasing nitrate concentrations with increasing well depth. The lack of trend also suggests that abandoned, poorly constructed or poorly located wells may be transmitting contaminants deeper into the aquifers.

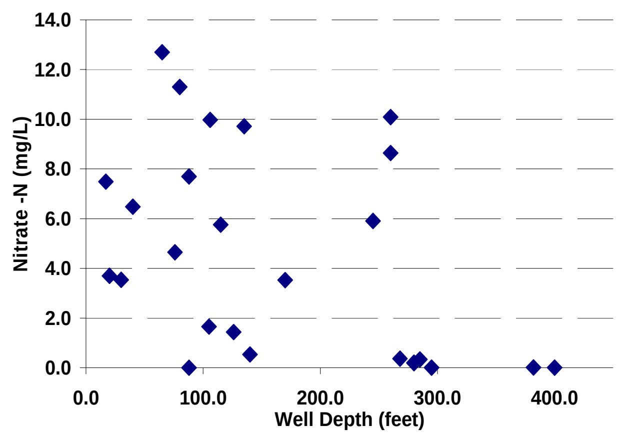

Figure 5 – A graph of nitrate-nitrogen versus well depth from November 2005 sampling event.

High chloride concentrations were present in ground water samples from both the sand and gravel aquifer and the bedrock aquifer beneath the north-western area (lower Dog Creek) of the community. In lower Dog Creek Road, bedrock wells with high chloride concentrations usually had relatively low concentrations of nitrate-nitrogen. In comparison, sand and gravel wells with high chloride concentrations usually had high nitrate-nitrogen concentrations.

The high chloride but low nitrate concentrations in the lower Dog Creek Road bedrock wells suggests that the chloride in these wells could be from sources other than sewage. Potential sources of chloride include the storage and use of road salt, water softeners and naturally occurring chloride in the marine sedimentary rock.

Although good cross-sections of the aquifers were sampled, not every well in the community was tested during the study. The sampling data suggests that poor quality ground water is wide spread in the study area, and well owners are strongly encouraged to test their water periodically to ensure the water is safe to drink. Well owners can contact the local Health Protection Office of the Interior Health Authority for help in interpreting their own water quality testing results.

How do we know the data is valid?

As part of the Dog Creek ground water study, quality control (QC) samples were collected to check for sampling and analytical errors and confirm the accuracy of the data. Triplicate samples were collected from some wells and submitted to the laboratory as separate samples to examine the variability of water quality and accuracy of the lab (*field replicates*). The QC results found sample contamination and variability among the field replicates did not affect study conclusions.

Are there laws to protect drinking water?

The *Drinking Water Protection Act* came into force in May 2003. This legislation provides a detailed and comprehensive framework for drinking water protection. The legislation is administered by the B.C. Ministry of Health and the Regional Health Authorities such as Interior Health. The Ministry of Environment shares responsibility for protecting water quality and regulates well construction, operation and closure through the *Water Act* and the Ground Water Protection Regulation.

The Sewerage System Regulation administered by the Interior Health Authority and the Municipal Sewage Regulation administered by the Ministry of Environment, govern the installation of onsite septic systems in Dog Creek.

The Ministry of Environment's Ground Water Protection Regulation came into full force on November 1, 2005. The regulation establishes standards to ensure wells are properly drilled, sealed, maintained and closed. Wells that are not properly constructed or closed pose a risk to drinking water quality.

Private well owners need to be aware of the new ground water regulation and how it applies to them:

- Water wells must now be constructed by qualified well drillers.
- Pumps for water wells must be installed by qualified well pump installers.
- A registry of qualified drillers and pump installers can be found online at http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/index.html

All new water supply wells have to be constructed to minimum standards that include:

- A surface seal to prevent contaminated surface water from entering the well;
- A secure vermin-proof well cap;
- A minimum clearance of 30 cm (1 ft) from the top of the well casing to the ground surface and grading to drain surface water away from the wellhead; and,
- A well identification plate.

Private well owners need to maintain their wells to keep them safe and sanitary. This means ensuring the well stays securely capped, the surface seal is not damaged and the wellhead is not altered. Owners of wells constructed before November 1, 2005, must ensure a secure well cap, or well cap and cover, is installed by October 31, 2007. A well cap prevents contaminants from getting into the well and reduces the danger of a child or animal falling into the well.

If a well is not in use, the well owner is required to deactivate or close the well. Deactivating a well means capping, securing and protecting the well while it is not in use. Closing a well means filling the well in with backfill and sealant. Only qualified well drillers can close drilled wells.

Study Conclusions

We can conclude from the study results that:

- Human activity is negatively impacting the ground water quality in Dog Creek. Over half of the wells sampled had a nitrate-nitrogen concentration equal to or greater than 3 mg/L.
- Canadian Drinking Water Quality Guidelines for nitrate-nitrogen were exceeded in 5 water wells out of the 28 wells sampled.
- The water well supplying the Dog Creek Elementary School with potable water was one of the 5 wells exceeding the Canadian Drinking Water Quality Guideline for nitrate-nitrogen (school has stopped using ground water for drinking water).
- The greatest occurrence of nitrate contamination was in the sand and gravel aquifer (Aquifer 152).
- Canadian Drinking Water Quality Guidelines were also exceeded for TDS (27 wells), turbidity (20 wells), chloride (7 wells), sulphate (1 well), iron (8 wells), manganese (3 wells) and sodium (9 wells), out of the 28 wells sampled.
- The bedrock aquifer and the sand and gravel aquifer both have a low vulnerability rating due to an overlying layer(s) of low permeable soil. However, the low permeable layers have not prevented contaminants from reaching the aquifers.
- Bond Lake is not a source of nitrogen in the Dog Creek Road aquifers.

Future Directions

The Ministry of Environment will continue to monitor ground water quality in the provincial observation well on Dog Creek Road. Ground water samples from the observation well will also be analyzed for additional parameters to investigate the type of human impact and nutrient sources occurring, i.e. sewage disposal, fertilizer use.

The Cariboo Regional District maintains a feasibility reserve fund to study the merits of establishing new water and sewer services. Before utilizing these funds, the Cariboo Regional District has to be assured that the majority of property owners knowing the relative costs, wish to proceed with the establishment of a new service. With assistance from the Regional District, a locally established committee of effected properties owners would determine the level of public interest by way of a public petition. Residents interested in the committee or a feasibility study should contact Mitch Minchau, Manager of Environmental Services for the Cariboo Regional District, (250) 392-3351.

Contacts

Fore further information on this study, please contact:
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If you would like specific information regarding health issues, please contact:
Dan Ferguson, C.P.H.I. (C)
Assistant Director, Interior Health Authority
(250) 851-7300

Further Information

General information on ground water in B.C.
http://www.env.gov.bc.ca/wsd/

Ground Water Protection Regulation
http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/index.html#leg

Drinking Water Protection Regulation
http://www.healthservices.gov.bc.ca/protect/water.html#bulletin

Health Canada's Drinking Water Guidelines
http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/index_e.html

Nitrate in Ground Water Fact Sheet
http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library.html

Acknowledgments

We would like to thank the residents of Dog Creek Road for granting access to their wells for sampling. Thanks also to Ministry of Environment staff Mike Wei, P.Eng, and Dr. Digby Horne of the Interior Health Authority, for their review and comment.

Table 1
Summary of water quality concentrations from 28 wells in the Dog Creek community

PARAMATER	UNITS	DWG[1]	TOTAL # SAMPLES	MINIMUM	MAXIMUM	AVERAGE	90th PERCENTILE
General							
pH	pH units	6.5 to 8.5	55	7.9	8.4	8.1	8.4
Total Dissolved Solids	mg/L	500[AO]	58	360	**2600**	**994**	**1444**
Turbidity	NTU	1	47	0.1	**547**	**51**	**119**
Alkalinity (total)	mg/L	-	58	238	854	551	740
Total Hardness (CaCO3)	mg/L		59	19	1460	613	996
Dissolved Anions							
Chloride	mg/L	250[AO]	61	2.6	**487**	136	**275**
Flouride	mg/L	1.5	58	0.050	0.45	0.20	0.36
Sulphate	mg/L	500[AO]	61	12	**866**	121	241
Dissolved Nitrogen							
Ammonia	mg/L	-	56	0.005	1.410	0.204	0.945
Nitrate	mg/L	10	58	0.002	**12.70**	3.91	**10.22**
Nitrite	mg/L	-	58	0.002	0.601	0.020	0.018
Total Metals							
Aluminum (Al)	µg/L	200[2]	60	0.3	55	4.6	6.2
Antimony (Sb)	µg/L	6[2]	60	0.01	0.36	0.11	0.22
Arsenic (As)	µg/L	10	60	0.10	3.80	1.30	2.50
Barium (Ba)	µg/L	1000	60	0.68	287	49	90
Beryllium (Be)	µg/L	-	60	0.02	0.30	0.13	0.20
Bismuth (Bi)	µg/L	-	47	0.02	0.20	0.13	0.20
Cadmium (Cd)	µg/L	5	60	0.010	0.200	0.078	0.100
Chromium (Cr)	µg/L	50	60	0.200	12.00	3.38	7.10
Cobalt (Co)	µg/L	-	60	0.01	1.42	0.21	0.43
Copper (Cu)	µg/L	1000[AO]	60	0.34	126	32.9	84.3
Iron (Fe)	µg/L	300[AO]	60	1	**1410**	161	**610**
Lead (Pb)	µg/L	10	60	0.04	4.80	0.90	1.91
Lithium (Li)	µg/L	-	60	1.45	87.2	19.9	45.8
Manganese (Mn)	µg/L	50[AO]	60	0.08	**245**	25.5	**63.4**
Molybdenum (Mo)	µg/L	250[2]	60	0.24	12.3	4.20	9.76
Nickel (Ni)	µg/L	-	60	0.05	24.1	3.71	7.83
Selenium (Se)	µg/L	10	60	0.20	7.00	1.92	4.00
Silver (Ag)	µg/L	-	60	0.020	0.200	0.138	0.200
Sodium (Na)	mg/L	200[AO]	60	29	**361**	125	**239**
Strontium (Sr)	µg/L	-	60	3.2	3890	846	1731
Thallium (Tl)	µg/L	-	60	0.004	0.160	0.062	0.121
Tin (Sn)	µg/L	-	60	0.010	0.300	0.085	0.100
Uranium (U)	µg/L	100	60	0.02	76.4	6.69	9.81
Vandium (V)	µg/L	-	60	0.07	11.3	5.06	10.25
Zinc (Zn)	µg/L	5000[AO]	60	0.10	1080	63.3	246

Notes:

1. DWG = Guidelines for Canadian Drinking Water Quality – Health Canada
2. British Columbia Water Quality Guidelines (Criteria): 1998 Edition
3. AO = Aesthetic Objective
4. 90th Percentile = 90% of all samples were less than this value

Figure 3

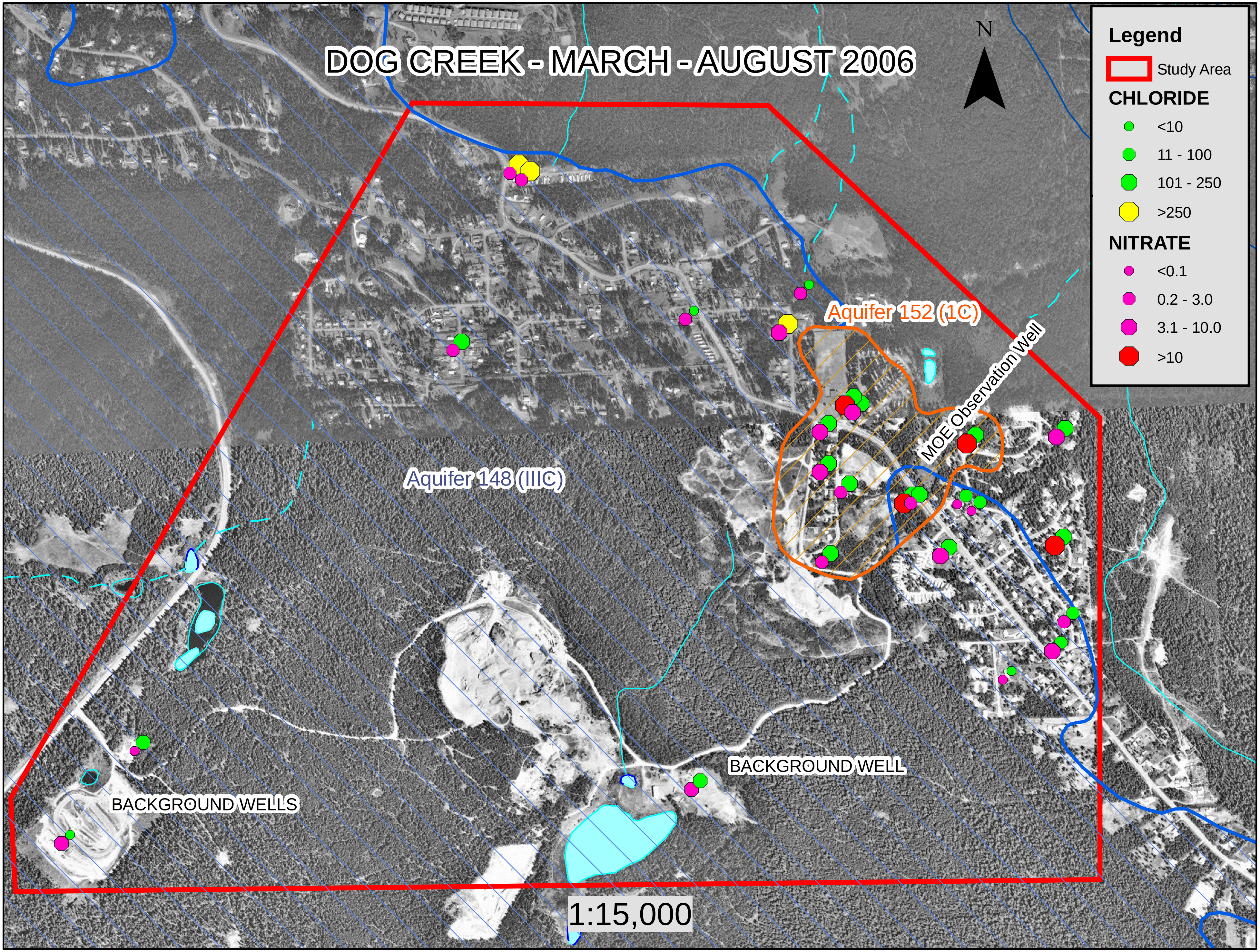
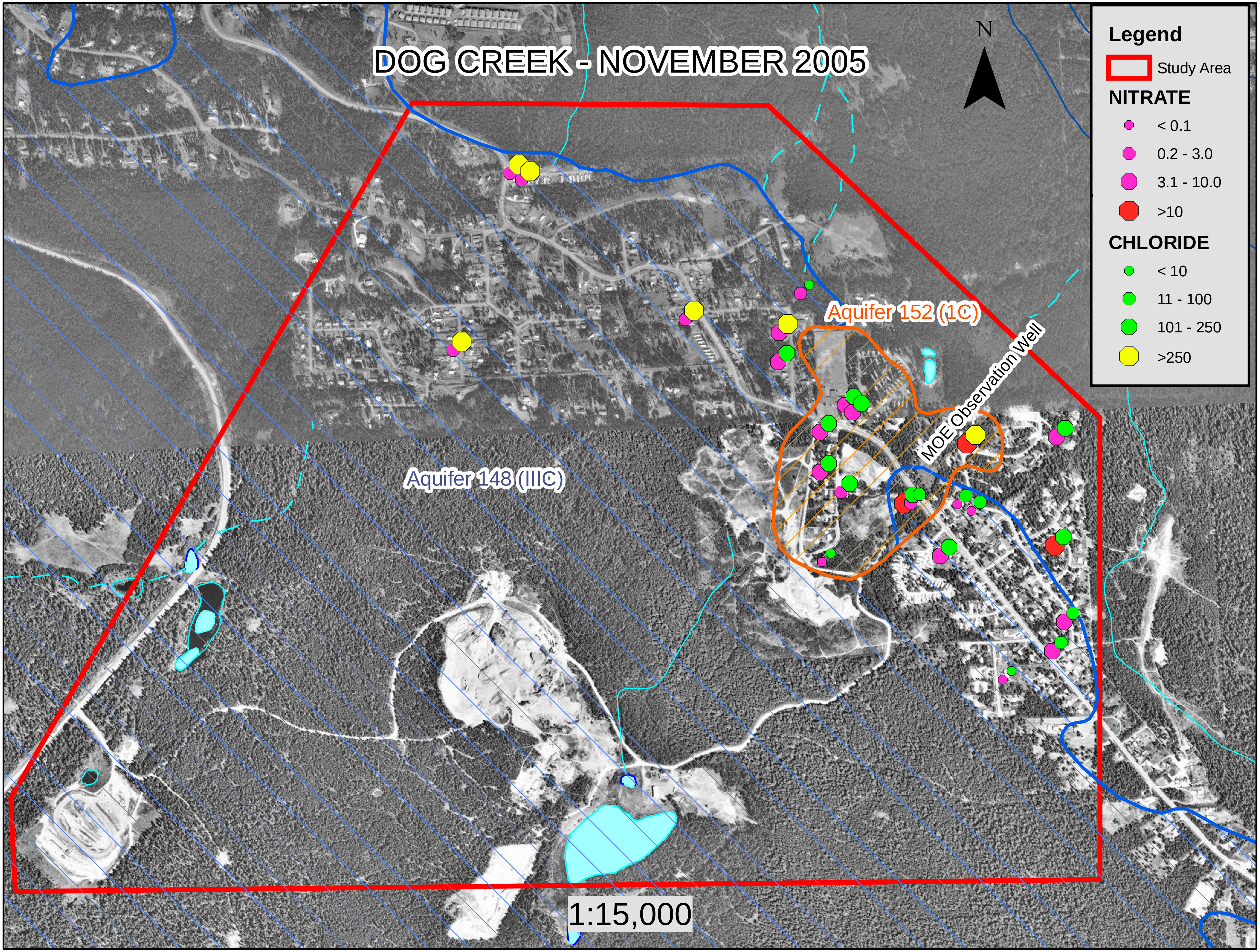

DOG CREEK - MARCH - AUGUST 2006
N
Legend
Study Area
CHLORIDE
<10
11 - 100
101 - 250
>250
NITRATE
<0.1
0.2 - 3.0
3.1 - 10.0
>10
Aquifer 152 (1C)
MOE Observation Well
Aquifer 148 (IIIC)
BACKGROUND WELL
BACKGROUND WELLS
1:15,000

Figure 2


DOG CREEK - NOVEMBER 2005
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Legend
Study Area
NITRATE
< 0.1
0.2 - 3.0
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11 - 100
101 - 250
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Aquifer 152 (1C)
MOE Observation Well
Aquifer 148 (IIIC)
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