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Groundwater Use Determination at Contaminated Sites

It is estimated that more than 750,000 British Columbians rely on groundwater wells for their drinking water. With increasing population, industrial, and agricultural growth and the potential impacts of climate change, now more than ever, we need to be planning and protecting our water resource to ensure it is sustainable for future generations.

The Contaminated Sites Regulation (the Regulation) contains requirements to ensure that groundwater at a site is suitable for current and future uses and is of adequate quality to protect adjacent water uses. This document explains how these provisions are applied by the ministry at contaminated sites throughout British Columbia. The relevant provisions in the Regulation include section 12 (2) and (5) and section 17 (5).

This guidance replaces our former Technical Guidance 6 entitled "Applying Water Quality Standards to Groundwater and Surface Water" last revised in June 2005.

The following terms used in this guidance are defined in the ministry's procedure entitled "Definitions and Acronyms for Contaminated Sites": agricultural land use, aquatic life water use, drinking water use, ecologically active zone, groundwater contamination source, industrial land use, irrigation water use, livestock water use, municipality, muskeg and qualified professional.

It is assumed that groundwater at a site is used for all defined purposes specified in section 12 (4) of the Regulation (aquatic life, drinking, irrigation and livestock) unless it can be shown otherwise. Further details in this guidance are provided to aid responsible parties and qualified professionals in determining groundwater use at a site.

Drinking water use

The circumstances that determine if drinking water use applies are presented below as questions. Depending on the responses, drinking water standards may or may not apply.

Question 1. Is the water currently used for drinking?

Drinking water use applies at or near any site where the groundwater is currently used for drinking water. For site investigation purposes, the presence of any drinking water wells within a radial distance of 500 metres from the downgradient extent of the groundwater contamination source must be established.

The presence of current drinking water wells near the source may be obtained from the Ministry of Environment's well database (available at the ministry's Water Stewardship Program website: http://a100.gov.bc.ca/pub/wells/public/) and by a door to door survey.

In addition, local municipalities, water utility owners, and Medical Health Officers may also have knowledge regarding the presence of water supply wells. The use of nearby surface water as a current drinking water source must also be considered. B.C.'s Water License Database (available at the Water Stewardship Program website: http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input) should also be queried to determine the presence of water licenses for drinking water uses in the vicinity of the site.

The presence of drinking water wells at distances greater than 500 metres must be evaluated on a case-by-case basis in consideration of potential adverse impacts on drinking water. This includes situations where preferential flow pathways are known to exist or where contamination plumes extend beyond 500 metres from the groundwater contamination source.

Well capture zone analysis may be performed to determine if drinking water wells located within a 500 metre radial distance are pumping at rates that will draw in contaminated groundwater. Capture zone delineation methods are outlined in the ministry's Well Protection Toolkit (available at the Water Stewardship Program website: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/acrobat.html).

The ministry expects qualified professionals to ensure that methods used for capture zone analysis are valid and appropriate for each circumstance. If it is determined that a multi-aquifer system underlies the site and the deeper groundwater is used as drinking water, refer to the section below entitled "multiple aquifer systems".

If water is currently used for drinking water, then drinking water standards would apply.

Question 2. Does the geological unit have a hydraulic conductivity less than or equal to 1 x 10^{-6} m/s or a yield less than 1.3 L/min?
Geological units with hydraulic conductivities less than or equal to 1 x 10^{-6} m/s are considered to have insufficient permeability to allow suitable water extraction for drinking water use.

If the geological unit is determined to have a hydraulic conductivity greater than 1 x 10^{-6} m/s then it must be shown that the aquifer yield is less than 1.3 L/min (500 gallons/day) to exclude drinking water use. This yield is considered the minimum rate required to produce enough water to supply a single family dwelling for domestic use (B.C. provincial allocation for domestic surface water licenses). An unconfined aquifer that is present only seasonally or has an average saturated thickness of 1 metre or less is considered incapable of sustaining a single family dwelling.

In situ field investigation is required when estimating formation hydraulic conductivity. The field tests should be conducted in accordance with ministry Technical Guidance 8 entitled "Groundwater Investigation and Characterization".

Instead of performing a pumping test, the Cooper-Jacob Approximation (Cooper H.H. and C.E. Jacob (1946); a generalized graphical method for evaluating formation constants and summarizing well field history. Am. Geophys. Union Trans. Vol. 27, pp. 526-534) is expected to address most circumstances at sites in B.C. and may be used. An example of the calculation is provided in the Appendix to this document. Where conditions and assumptions inherent in this method do not apply, the ministry expects the qualified professional to justify the use of alternate methods.

If the geological unit has a hydraulic conductivity less than or equal to 1 x 10^{-6} m/s or a yield less than 1.3 L/min, then drinking water standards do not apply.

Question 3. Is the natural quality of the groundwater such that it is unsuitable and untreatable for drinking water?
Groundwater containing a natural total dissolved solids concentration of 10,000 mg/L or greater or is contained within organic soils or muskeg is considered to be unsuitable and untreatable to be used as drinking water. There may be other situations where concentrations of naturally occurring substances make groundwater unsuitable for drinking water and these situations must be evaluated on a case by case basis. The ministry expects the qualified professional to show, using methods available in ministry technical guidance and protocols, whether or not the water quality is suitable for drinking.

If there is commercially available technology that can be reasonably used in public and domestic water supply systems to treat the water to meet drinking water standards (such as an ion exchange medium to treat nitrates, carbonates, iron and manganese) then the water is considered suitable for drinking.

If the natural quality of groundwater is such that it is unsuitable and untreatable for drinking water, then drinking water standards do not apply.

Question 4. Is the site currently industrial?
Drinking water use does not apply within the property boundaries of industrial land use areas unless the groundwater on the property is currently being used for drinking water. However, assessment of drinking water use for neighbouring properties is required if contamination has migrated off site.

If the site is currently used for industrial purposes then drinking water standards do not apply within the property boundary.

For all other groundwater conditions, drinking water standards apply.

Aquatic life, irrigation and livestock watering groundwater uses

Aquatic life groundwater use applies to all land located within a radial distance of 300 metres from the ecologically active zone of a surface water body containing aquatic life (please refer to draft Technical Guidance 15 to determine applicable water quality standards within 10 m of the ecologically active zone). Sufficient investigation must be conducted to ensure that any contaminated groundwater originating from a site has not migrated or does not have the potential to migrate to within 300 metres distance of the ecologically active zone. Aquatic life water use also applies at sites where there is the potential for contaminated groundwater to flow through preferential corridors that discharge directly to a surface water body containing aquatic life. For example, in an urban setting the potential exists for contaminated groundwater to be pumped directly to storm water discharge via underground dewatering systems.

Aquatic life water use does not apply when a site exists within a radial distance of 300 metres from a surface water body containing aquatic life and it is shown, using appropriate methods, that groundwater discharges to another surface water body located greater than 300 metres from the source.

If a site is considered agricultural land use or is within a provincial Agricultural Land Reserve (ALR) then irrigation and livestock watering uses apply. Irrigation and livestock watering uses will also apply if irrigation or livestock watering wells are within a radial distance of 500 metres from the downgradient extent of a groundwater contamination source. Well capture zone analysis as described in Drinking Water Use, Question 1 can be performed to determine if livestock or irrigation wells near or within the 500 m radial distance are pumping at rates that will draw in contaminated groundwater.

Multiple aquifer systems

Differing water uses may apply for multiple geological units overlying a deeper drinking water aquifer if a natural confining geological unit exists to protect the deeper aquifer. In this case it must be shown that the natural confining unit:

- is greater than or equal to 5 metres thick;
- has a bulk hydraulic conductivity that is less than or equal to 1×10^{-7} m/s;
- is relatively uniform and free of fractures; and
- is continuous across the extent and predicted migration of the shallow subsurface contamination.

It also must shown that contamination is contained within overlying geological units and has not penetrated to the deeper aquifer or within the lower 5 metres of the natural confining geological unit that protects this deeper aquifer and that these conditions will persist with time.

Drinking water use applies to the lower 5 meters of the confining unit that protects the deeper drinking water aquifer. Applicable water use in shallow aquifers overlying deeper confined aquifers must be assessed according to this guidance.

Differing groundwater uses for multiple geological units will not be considered if it is determined that dense non aqueous phase liquids (DNAPL) have contaminated the subsurface.

Applicable standards

Whether or not a groundwater source is suitable for direct use can be determined by comparing monitoring results with the applicable generic numerical water use standards in Schedules 6 and 10 of the Regulation. When multiple uses are determined at a particular site, the most stringent of the applicable standards will apply. Consult Technical Guidance 3, “Environmental Quality Standards” for further information.

Water management plans

A qualified professional should consider groundwater use designations in municipal or district water management plans when determining groundwater use for a site. In addition, it may be determined that drinking water use is not applicable at a site if provincial or local restrictions exist that prohibit the installation of drinking water wells in certain areas as a measure to protect human health from exposure to existing contamination in the subsurface.

Fractured bedrock aquifers

Determination of water use for a bedrock aquifer is unnecessary if it has been shown that groundwater contamination has not penetrated to the bedrock aquifer. However, field investigations are required to measure aquifer yield if groundwater contamination has migrated to a bedrock aquifer. The methods for determination of aquifer yield, as presented in this guidance, may not be suitable for use at fractured aquifer sites. Instead, the advice of a qualified professional should be obtained to plan and conduct a bedrock aquifer study.

Requesting a director's determination of water use

Site owners or operators may formally request a Director to make a determination about whether any of the water uses apply to a particular site. Such a request must be accompanied by supporting documentation prepared by a qualified professional.

Grandfathering provisions

Site investigations conducted six months following (date of final document) are expected to assess groundwater use in accordance with this guidance.

For more information, contact the Environmental Management Branch at site@gov.bc.ca

Appendix

Estimation of Aquifer Yield Using Idealized Well Function Equation

Application of Nonequilibrium Well Function Equation and Estimation of Aquifer Yield based on Hydraulic Parameters.

The Cooper and Jacob (1946) approximation to the Theis (1935) solution for radial groundwater flow to a pumping well is:

$$s = \frac{2.3Q}{4\pi T}\left[\log\left(\frac{2.25Tt}{r^2 S}\right)\right] \qquad (1)$$

Where:

Q = rate of pumping (m^3/s)
T = transmissivity of water bearing unit (m^2/s)
r = radial distance from well (m)
S = coefficient of storage (dimensionless)
s = water level drawdown (m) at pumping rate (Q) and distance (r)
t = time of pumping (s)

The equation is valid for large values of time (t) and/or small values of radial distance (r), such as will occur at a pumping well. Well yield Q may be expressed in terms of drawdown (s), hydraulic conductivity (K), and saturated thickness (b) and coefficient of storage (S) as follows:

$$Q = \frac{5.46(s)(K)(b)}{\log\left(\frac{2.25Kbt}{r^2 S}\right)} \qquad (2)$$

For use in estimation of aquifer yield, the equation may be simplified by incorporation of typical default values for less sensitive input parameters, as follows:

Where:

r = radius of well in m
S = 1.0×10^{-4} (confined aquifer), 1.0×10^{-1} (unconfined aquifer)
t = 100 days = 8640000 s
T = K x b,
Where: K = hydraulic conductivity (m/s)
b = saturated thickness of the aquifer in m.

In unconfined aquifers, a water level drawdown in excess of 70% of the saturated thickness does not significantly increase well yield. Consequently, screening the lower one-half to one-third of the saturated aquifer, corresponds to a maximum available drawdown (s_{max}) equal to 70% of the saturated thickness.

In confined aquifers, when the full saturated thickness of the aquifer is screened, this corresponds to a maximum available drawdown equal to 100% of the confining head (h_c).

Based on these design guidelines, maximum available drawdown may be expressed as:

- Confined unit: $s_{max} = (1.0)(h_c)(e)$
- Unconfined unit: $s_{max} = (0.7)(b)(e)$

Where:
h_c = confining head (base of the aquifer to the static water table)
b = saturated thickness (base of the aquifer to the static water table)
e = well efficiency

Substituting these available drawdown terms into the Cooper-Jacob expression (Equation 2), the well yield (Q) associated with utilization of the maximum available drawdown (s_{max}) can be calculated based onsite-specific values of saturated thickness (b), hydraulic conductivity (K), and (for confined units) confining head (h_c), as in the following example:

For a confined aquifer, 6-inch (0.0762m) diameter well screen:

$$Q = \frac{(5.46)(h_c)(K)(b)}{13.52 + \log[(K)(b)]} \qquad (3a)$$

For an unconfined aquifer, 6-inch (0.0762m) diameter well screen:

$$Q = \frac{(3.822)(K)(b^2)}{10.52 + \log[(K)(b)]} \qquad (3b)$$

Where:
b = saturated thickness of water-bearing unit (m)
h_c = confining head above top of water-bearing unit (m)
K = hydraulic conductivity of water-bearing unit (m/s)
Q = well yield (m^3/s)
e = well efficiency (assumed to be 100% for an ideal well)