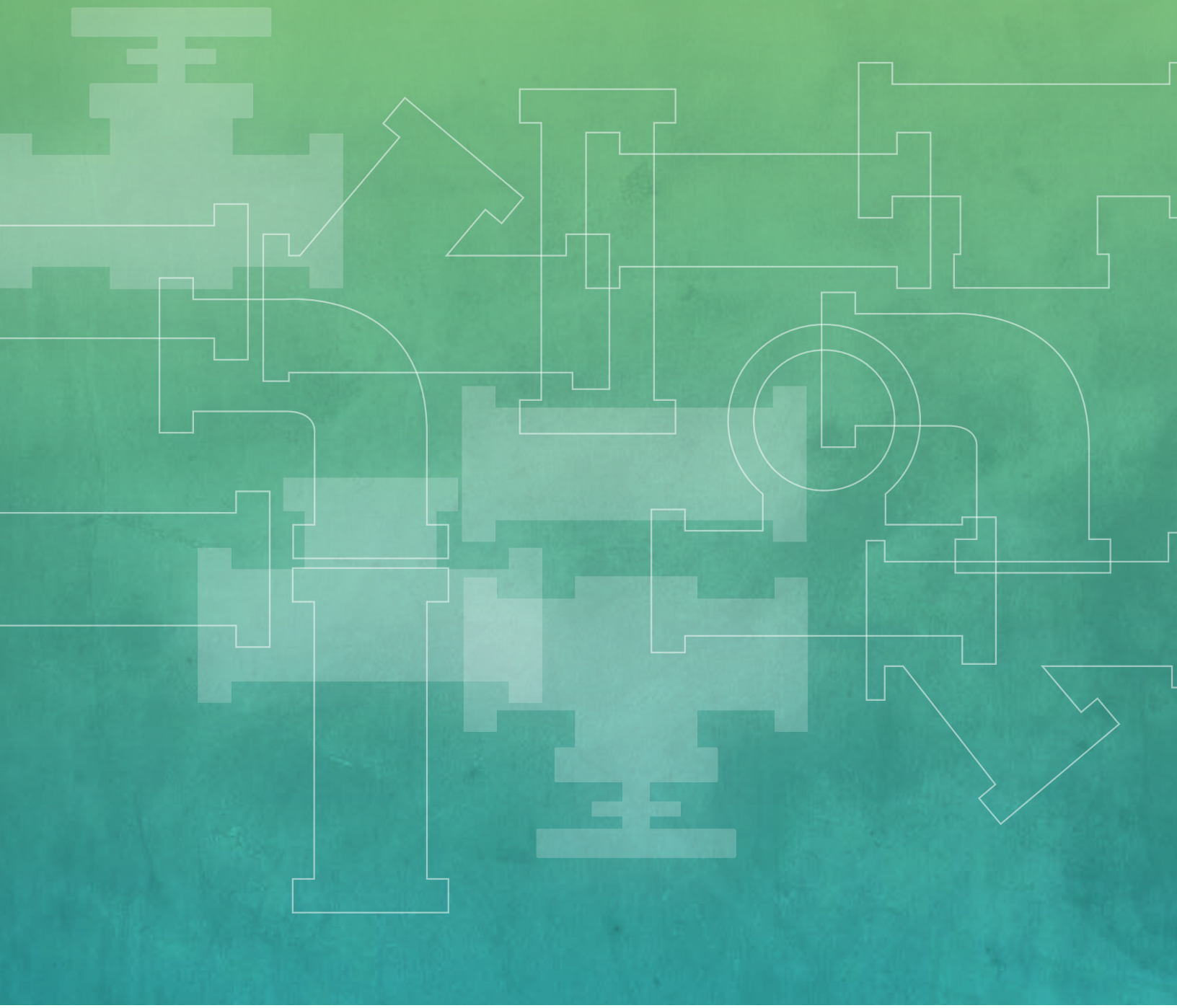
*Reference Guideline #1*

# Hydrogeological Impact Assessment



BRITISH COLUMBIA

Ministry of
Community, Sport and
Cultural Development

# Reference Guideline #1
# Hydrogeological Impact Assessment

Hydrogeological assessments are required for some subdivision applications when triggered by various criteria such as reduced parcel sizes or sensitive features. The primary reasons for hydrogeological assessments are to protect against groundwater and surface water contamination, and to limit groundwater mounding.

Nitrate-nitrogen exists in ionic form in solution and is therefore mobile in groundwater. Additionally, the natural attenuation of nitrate via denitrification and other processes may be limited and slow to occur, and it can persist in groundwater for a time frame of years to decades. Phosphorus levels are a concern where elevated concentrations in surface water can result in algal blooms; this could potentially be caused by onsite systems which contribute nutrients to groundwater, which then feeds surface water. However, phosphorus tends to associate with soil particles and is much less mobile in groundwater than nitrate-nitrogen.

Human microbial pathogens can contaminate aquifers and groundwater, resulting in a high human health risk. Contamination with fecal coliforms (E. coli), viruses, and protozoa (such as Giardia and Cryptosporidium), can occur from on-site sanitation systems, sewers, animal feces, wastewater or sewage sludge applied in agriculture. Faecal coliforms are generally not a concern if separation distances are met, and there is sufficient depth of soil. Factors such as soil type (highly permeable materials) and the hydrogeology of the aquifer will determine the distance these pathogens may travel and the length of time they may remain viable in an aquifer.

Table 1 provides information on the characteristics of the contaminants of concern.

**TABLE 1.** *Characteristics of contaminants of concern*

| CONTAMINANT | HEALTH CONCERN OR ENVIRONMENTAL CONCERN | GROUND WATER OR SURFACE WATER CONCERN | MOBILITY IN SOIL ENVIRONMENT (CONSIDERING BOTH SOIL AND AQUIFER MEDIA) |
|---|---|---|---|
| ***Nitrate-Nitrogen*** | Health | Ground water and Surface water | High |
| ***Phosphorus*** | Environmental | Surface water | Low-Moderate |
| ***Fecal Coli forms*** | Health & Environmental | Ground water and Surface water | Low-High |
| ***Virus/Protozoa*** | Health | Ground water and Surface water | Moderate-High |

# Cumulative Impacts

There are six primary cumulative effects this Guideline attempts to address.

1. Elevated concentrations of nitrate-nitrogen in groundwater that is used for drinking water.
2. Elevated levels of nitrate-nitrogen or phosphorus in groundwater which feeds discharges to surface water sources.
3. Transport of effluent containing elevated levels of nitrate-nitrogen and/or phosphorus, through subsurface flow to surface water.
4. An elevated concentration of fecal coliforms in groundwater used for drinking water.
5. Groundwater table mounding from high density or multiple onsite sewerage systems in an area.
6. Groundwater contamination from viruses and protozoa.

## IMPACT 1: NITRATE IN GROUNDWATER USED FOR DRINKING WATER

Nitrate contamination of groundwater is a risk where the following conditions exist:

- Unconfined, partially confined or perched aquifer under or in close vicinity to an onsite sewerage system;
- Unconfined, partially confined or perched aquifer used as a drinking water source (current or future use);
- Permeable soil between onsite system and aquifer; and
- Minimal depth to groundwater.

## IMPACT 2: NUTRIENTS IN GROUNDWATER DISCHARGES TO SURFACE WATER

Elevated concentrations of nutrients in surface water due to groundwater discharge are of concern when the following conditions exist:

- Unconfined, partially confined or perched aquifer under or in close vicinity to an onsite sewerage system; and
- Unconfined, partially confined or perched aquifer intersects with the ground level.

The potential for phosphorous or nitrate contamination of surface water can be addressed by ensuring sufficient separation between an onsite system and surface water, and accounting for local soil type and chemistry.

## IMPACT 3: FECAL COLI FORMS

Fecal coliforms, (specifically E. Coli), are a concern in groundwater used for drinking water or in groundwater that feeds surface water. Effluent from onsite systems can contain elevated levels of fecal coliforms. However, coliforms are typically only an issue if the following condition exists:

- Insufficient depth of soil
- Shallow depth to groundwater
- Preferential flow paths including hetereogeneous course grained sediments, fractured bedrock or karst aquifers, shallow and/or excavated wells, wells with missing or inadequate surface seals, wells screened across multiple layered aquifer systems.
- Preferential flow paths (heterogeneous coarse grained materials, fractured bedrock and karst formations) increase the travel distance and longevity of pathogens.

### IMPACT 4: GROUNDWATER MOUNDING

Groundwater table mounding can occur under the following conditions:

- Unconfined, partially confined or perched aquifer under or in close vicinity to onsite system;
- Minimal depth to groundwater (typically less than 3m); and
- High density, multiple onsite sewerage systems in an area.

### IMPACT 5: VIRUSES AND PROTOZOA

The migration of viruses and protozoa from a contaminated source is dependent on the following:

- Soil conditions (coarse or fine media will determine adsorption of viruses and length and time of travel);
- Soil ph, water content and temperature (as temperature increases, survival time of virus decrease);

## Criteria for Requiring Hydrogeological Assessment

In summary, the sensitive features which contribute to the potential six cumulative effects of concern are:

- Unconfined, partially confined or perched aquifer under or in close vicinity to an onsite sewerage system;
- Unconfined, partially confined or perched aquifer used as a drinking water source *(current or future use)*;
- Permeable soil between onsite system and aquifer;
- Minimal depth to groundwater (typically less than 3m);
- Unconfined, partially confined or perched aquifer intersects with the ground level;
- Onsite system located within close proximity to surface water;
- Insufficient depth of soil;
- Site conditions which may contribute to lateral transmission of effluent to surface water (e.g. High permeability soil and shallow depth of soil over confining layer, karst rock, etc.); and
- High density development; or
- Water well located <30 m (100 ft) separation distance from the septic field installation.

## ASSESSMENT PROCESS

The purpose of a hydrogeological impact assessment is to ensure that the combined effluent discharges from all the individual onsite sewerage systems in a subdivision will have a minimal effect on the groundwater and on adjacent properties.

Subdivision authorities can consider support for subdivision applications involving onsite sewerage systems and hydrogeological assessments where the applicant has met the following criteria:

- Demonstrate the ability of the site to support an onsite sewerage system;
- Determine the representative nitrate-nitrogen levels in the receiving groundwater – to be determined through collection of groundwater samples from various locations on and adjacent to development site – provide clear rationale for number of sampling events, period of time over which sampling is undertaken (capturing season variations), and the manner in which this information is used in the assessment.

  *Note: the existing background nitrate-nitrogen concentrations (relative to nitrate sources), and the susceptibility of groundwater to contamination should be discussed.*
- Is advised that the subdivision authority not support development in areas where background nitrate-nitrogen concentrations in groundwater exceed 5mg/l. The approving authority may not support development if the applicant cannot provide reasonable rationale for existence of nitrate concentrations in groundwater.

  *Note: If applicant can demonstrate that existing levels of nitrates result from historical agricultural practices on the site, there may be room for argument that nitrate levels will decline after development, within a reasonable time frame.*
- demonstrate that the area is not obviously hydrogeologically sensitive (e.g. karstic areas, areas of fractured bedrock exposed at surface, areas of thin soil cover, or areas of highly permeable soils).

It must be recognized that the assumptions required for allowing a predicted level of 5 mg/L of nitrate-nitrogen to be used as a boundary target criterion, for exempting lots of one hectare (2.5 acres), or for using nitrate-nitrogen as the critical contaminant etc., may not be technically supported in every case. It must also be recognized that, as research continues, information and technologies may become available which warrant minor or substantial revisions to this document.

The following are fundamental considerations to be considered when preparing a hydrogeological assessment:

- Groundwater impact predictions should be calculated for the development site property boundary. Recommendations should be made regarding the optimum location and orientation of discharge areas. In general, the attenuative capabilities of a site can be optimized by maximizing separation distances between individual onsite sewerage systems and down-gradient wells and property boundaries.
- Where applicable, the impact of the onsite discharge of sewage effluent into surface water.

If evaluation of phosphorus impacts and migration is undertaken, septic tank effluent can be assumed to have a phosphorous concentration between 5mg/L and 15 mg/L. The Level of treatment provided in the soil environment is highly variable (0-100%) and depends on the type and thickness of unsaturated soils; conservatively, dilution with rainwater can be used to predict the downstream concentrations.

## GROUNDWATER MOUNDING

A groundwater mounding assessment should be required if the depth to groundwater is less than 3m, there is an unconfined aquifer in the vicinity, and high development density is proposed (parcels smaller than on hectare).

Assessments which show mounding of greater than or equal to 0.5m should not be approved.

## SYSTEM ISOLATION CONSIDERATIONS

Where proposed parcel sizes are less than 1 hectare (approximately 2.5 acres), the proponent and/or the consultant is/are responsible for assessing the potential risk to groundwater. Developments will normally be considered as low risk where it can be demonstrated that sewage effluent is hydro-geologically isolated from existing or potential supply aquifer(s).

In making such an assessment, the proponent and/or the consultant should complete two important steps:

- Evaluate the most probable groundwater receiver for sewage effluent: its definition should be defended by hydrogeological data and information obtained through physical evaluations, potentially including but not limited to test pits, auger holes and test drilling programs; and
- Define the most probable lower hydraulic limit or physical boundary of the groundwater receiving the sewage effluent.

The consultant should clearly define those portions of the subsurface that will be affected by the effluent. Detailed predictions of the shape of individual contaminant plumes and a description of specific contaminant concentrations over space and time may not be required. The potential for isolation should be assessed on a site-specific basis and may involve assessments of geologic and/or hydraulic boundaries (note: this may require hydrogeologic assessment of lands up to 500 meters beyond the actual development boundary). In some cases, it may be necessary to demonstrate isolation from sensitive surface water environments.

When it is demonstrated that the sewage effluent will not enter supply aquifers, the parcel density of the proposed development may be dictated by factors such as the need for sewage system replacement or contingency area, and by the minimum distances between onsite sewerageInstallations and wells as defined by the Sewerage System Regulation.

## CONTAMINANT ATTENUATION CONSIDERATIONS

Where it cannot be demonstrated that the sewage effluent is hydrogeologically isolated from an aquifer, a hydrogeologic study is required to assess the risk that the development's onsite sewerage systems will cause contamination of nitrate-nitrogen in groundwater to exceed 5mg/L at the down-gradient property boundary. As described below there are various methods by which this detailed risk assessment can be done.

## MONITORING-BASED ASSESSMENTS

This Guideline recognizes that groundwater, infiltration precipitation and sewage effluent will not be completely mixed at the property boundary. It is also recognized that processes such as absorption, dentrification, filtration and biodegradation may attenuate contaminants as the effluent passes down through the unsaturated zone and moves into the saturated zone. Since these processes are extremely difficult to quantify with any accuracy, they are usually only considered as a safety factor.

- **EXISTING DEVELOPMENT**

  In some situations, there may be nearby onsite sewerage system-based development in a similar hydrogeological environment. If this development has been in place for a lengthy period, information on existing groundwater quality could be used to demonstrate the combined effect of all available attenuated processes. This empirical information may then be used to help predict the impact of the proposed development. The onus is on the proponent and/or the consultant to demonstrate adequately that:

  - The existing and proposed developments are located in similar hydrogeological environments;
  - Sewage effluent (quantity and quality) from the existing and proposed developments are comparable; and
  - Monitoring produces results that accurately represent water quality conditions beneath the existing development – the consultant should provide a clear rationale for the number of times the site is sampled, the period of time over which the sampling has been undertaken (capturing seasonal variations), and the rationale for the way in which this information is used in the assessment.

- **PHASED DEVELOPMENT**

  In situations where there is no existing development, it may be possible to develop lands considered in the planning document in phases, beginning with the up-gradient portion.

  Information obtained from monitoring effluent discharged from onsite sewerage systems in the up-gradient phase, and its impact on groundwater, can then be used to determine the extent to which the down-gradient portion of the site can be developed. Before approving such a phased development, the subdivision authority should be satisfied that adequate planning controls are in place to regulate development of the down-gradient portion of the site.

## PREDICTIVE ASSESSMENT – RESIDENTIAL DEVELOPMENT

The approving officer should require the following considerations and assumptions in assessing the combined impact of individual onsite sewage systems at the boundary of residential developments:

- **CONTAMINANT SOURCE:** In most cases total nitrogen (all species) converted to nitrate-nitrogen is considered as the critical contaminant. For the purposes of predicting the potential for groundwater impacts, a nitrate loading of at least 40 grams/parcel/day per residential dwelling unit shall normally be used (based on expected actual flows of 1,000 L/day and a minimum value of 40 mg/L nitrate-nitrogen in the discharge from an onsite sewerage system treating domestic/household sewage.)
- **CONTAMINANT ATTENUATION:** In assessing contaminant attenuation, only dilution should be accepted by the municipality as a quantifiable attenuation mechanism for nitrate.

Dilution models involve dilution with infiltrating precipitation. Mixing with groundwater flowing through the site will normally not be allowed because it is usually not possible to control up-gradient land uses. Flow-through will not be considered where sensitive hydrogeological conditions exist. However, where up-gradient lands have been fully developed for a considerable period of time, the quantity and quality of groundwater flow available to dilute the effluent entering the receiving groundwater may be considered.

The amount of available moisture surplus should normally be obtained from Environment Canada through a calculation based on weather data (precipitation, temperature) using various models (e.g. Thornthwaite). Where available, reliable, long-term, site-specific information, obtained for detailed water balance and/or groundwater

studies, can be used. Estimates of the surplus amount that infiltrates the ground should be based on site-specific factors such as soils, topography, surface geology, and impermeable areas (including rooftops and paved areas). The volume of sewage effluent, if used as dilution water in mass balance calculations, should not exceed 1,000 L/day/parcel.

Mathematical (computer) models may be used to assess the impact potential. Although the selection of model software will be left to the proponent, the approving officer and /or health authority should be provided with information on the model's validation and how its limitations and assumptions affect the results. All model simulations should include appropriate sensitivity analyses. The approving officer should allow the use of only those dilution models that are reasonable and can be defended on a site-specific basis.

## PREDICTIVE ASSESSMENT – INDUSTRIAL/ COMMERCIAL DEVELOPMENT

This guideline only applies to developments that have an average daily flow of less than 22.7 $m^3$/ day/lot. Developments with larger flows should be assessed by the Ministry of Environment (MoE). In addition, the sewage assessed should consist of domestic wastes only. No industrial/ commercial cooling or process wastewater is to be considered. The Municipal Wastewater Regulation (MWR) also applies to all discharges to water and all uses of reclaimed water (except from a single family residence).

The nitrate loading from industrial/commercial onsite sewerage systems can vary greatly depending on the type and intensity of use. Since specific uses for each parcel or block are not necessarily known at the subdivision application and review stage, it is necessary to determine how much nitrate can be discharged from each onsite sewerage system without exceeding the recommended 5 mg/L threshold at the property boundary.

The following procedure is recommended for use in setting maximum allowable effluent flows for each parcel:

### AVAILABLE INFILTRATION

The amount of available moisture surplus should normally be obtained from Environment Canada (through calculation based on weather data using various models)

- Where available, reliable, long-term, site-specific information, obtained from detailed water balance and/or groundwater studies can be used.
- Estimates of the amount of moisture surplus that infiltrates into the ground should be based on site-specific factors such as soils, topography, surface geology, and impermeable areas (including rooftops and paved areas).

### MAXIMUM ALLOWABLE FLOW

The maximum allowable flow for each lot or block in the industrial/commercial development can be calculated by dividing the amount of available infiltration (from (a) above) by a factor of three.

### MAXIMUM NUMBER OF USERS

Restrictions regarding the allowable number of users will normally be incorporated as recommendations in the consultant's assessment, and the recommendations should be implemented by provisions contained in the development agreement between the proponent and the municipality.