

**Intrinsic Susceptibility Index Protocol**

**Excerpts from the MOE, 2001 Technical Terms of Reference for the 2001/2002  
Groundwater Studies  
Pg 4-9, Schedule B  
Pg 27 – 35, Schedule C.**

**Data Gaps** – The ideal is to use all of the data giving regard to the provenance including anecdotal information such as spot measurements and recollections, by assigning relative importance to the individual data points and components. Where data is absent on any portion within the sequence or having a poor spatial distribution across the study area this must be noted early within the study process. These identified data gaps can be used to plan for and obtain necessary data through the study process.

In some cases, data gaps can be seen and thereby potentially guide the process for the collection of further relevant data. This step allows the clear transition from raw data to the more complex data analysis processes possible through the use of geostatistical, relational database, and GIS mapping tools.

**Data Validation** – The validation process for bringing together the best and most reliable data within a given study area may be time consuming, however, without a documented validation process to define the data set used in preparing derived map products, the results are likely suspect. Data validation processes must select for the data that best represents the entire groundwater active sequence in a study area in overburden as well as bedrock. See details on standardization objectives, methods and rules presented in *Schedules A through G* later in this document. Data selection and validation rules, when used, must be stated and included in the metadata. The following are typical data validation processes:

- *Location* – checking congruity between various data sets such as geographic references such as county, township, lot and concession, physical features, air photos, parcel fabric, digital elevation model, historical topographic maps used to estimate map-based co-ordinates, use of GPS measured georeferenced co-ordinates, use of existing reliability coding, matching well owner names, etc;
- *Elevation* – checking congruity between water well elevation with historical topographic maps, the provincial digital elevation model (DEM), benchmarks, geodetic survey information, use of GPS, use of elevations on water bodies such as streams, reservoirs, lake and wetlands that preserves the direction and descent of surface flow representing the establishment of drainage areas such as watershed and subwatershed, recognizing closed drainage areas such as hummocky terrain and karstic areas;
- *Interpretation* – checking congruity, confirmation and evaluating the balance of evidence using geophysics analysis, sample results, core analysis, outcrops, geotechnical boreholes as well as oil and gas boreholes to corroborate a sequence of geological environments of deposition/erosion and corresponding paleoecological environments, identifying hydrogeological settings and active hydrogeological units such as aquitards and aquifers, corresponding water quality, age, and major flowpaths accounting for both transient and steady-state conditions for both horizontal and vertical movement. There has been consensus about applying the GSC geomaterial protocols early in the borehole geology data interpretation; and
- *Metadata* – The provincial metadata standard available through MNR Land Information Ontario is to be used for the groundwater studies. Each of the data and map products will be registered as a record and details regarding data validation will be entered in the areas entitled “Data Sources” or as appropriate in other sections. See *Schedule B* in particular for an example for documenting the metadata related to the GSC Geomaterial Protocol.

## **2.2 Methodology for Defining Groundwater Intrinsic Susceptibility**

**Purpose** – In general, groundwater intrinsic susceptibility maps identify areas where contamination of groundwater is more (or less) likely to occur as a result of surface contamination. It is anticipated that land managers, municipal planners, and facility owners and operators will be able to use groundwater intrinsic

susceptibility (GwIS) maps showing the areas of high, medium, and low intrinsic susceptibility and index values at point locations. The GwIS maps can be used as a general guide to preserve existing groundwater resources by diverting potentially harmful land use from areas of higher groundwater susceptibility to areas of lower groundwater susceptibility. Furthermore, recognizing that today's groundwater contamination is tomorrow's surface water contamination, the maps can be effective in preserving the ecosystem functions linked to the groundwater systems.

**Rationale** – The rationale for this method is linked to time of travel. The vulnerability is tied to arrival of a contaminant at the water table and or the shallowest aquifer. The method is not geared to assessing a specific contaminant, contaminant group or human activity. This method assesses intrinsic vulnerability or susceptibility with limited consideration of the specific attributes of the hydrogeologic system or the behavior of contaminants. The two key attributes considered are the depth to water table and the conductivity of geologic material in the unsaturated zone (or above a confined aquifer). Although the method considers only the intrinsic susceptibility of the shallowest aquifer, deeper aquifers will be of interest to the local municipality. A modification of this method that uses an “effective thickness” instead of depth to water table, where the effective thickness represents the time of travel to the aquifer, would be a useful first cut at determining the intrinsic susceptibility of aquifers below the shallowest aquifer. This method is also used for determining the intrinsic susceptibility of confined shallow aquifers. Here, the depth to the aquifer is used instead of the depth to water table.

Intrinsically, fine unfractured media retards contaminant migration whereas fractured media, or coarse porous media, provides faster travel times and less retardation and hence more vulnerability. For example 20 metres of silt over a confined aquifer would have a low intrinsic susceptibility. But 10 metres of clean coarse sand or fractured rock would have a high susceptibility to contamination.

There are other factors that could be used to improve the understanding of a system's intrinsic susceptibility to contamination. Such factors may include gradients, recharge and discharge, flow paths and local geology. This information can be used to adjust the intrinsic susceptibility values.

This method presumes sufficient water well records and topography information are available to predict water table with certainty over the geographic area. In some areas, insufficient water wells, lack of a digital elevation model, or other issues may preclude the use of water table. In these cases, an “effective thickness” may have to be used that best approximates depth to water table.

**Goal** – Mapping of groundwater susceptibility should be undertaken using the MOE Water Well Information System (WWIS) as a primary data source. Vulnerability mapping is a tool that can be used to make planning decisions to protect groundwater resources and its ultimate use.

A key product is mapping of the groundwater intrinsic susceptibility to contamination at different levels of susceptibility (e.g., low, medium and high.) The mapping requires a careful assessment of the groundwater system and then moving to identify critical factors that can be used in the mapping of vulnerability. Decisions about additional factors and their application going beyond the method described here rest with the groundwater expert and the local study teams, in consideration of the needs of the product users. The MOE requires that the following methodologies be used as a minimum standard.

**General Procedures** – The hydrogeologist must develop a conceptual model of the hydrogeologic system for which the intrinsic susceptibility mapping is to be created. Developing a hydrogeologic conceptual model will require the expertise of an experienced hydrogeologist. The hydrogeologist can then determine the critical factors that must be assessed and integrated into the susceptibility assessment.

In the context of the data available from the MOE Water Well Information System (WWIS), groundwater intrinsic susceptibility can be inferred from the well geology, water table position, vertical gradients and possibly the screen location. The method prescribed herein will focus on the geology and water levels alone. Screen locations are considered to be often more reflective of a deeper ‘production aquifer’, rather

then a surficial aquifer with important ecosystem functions. Screen locations are therefore not used in the methodology, but may be considered for any additional maps assessing the deeper aquifers.

The method is based on calculating a susceptibility index at each well, then mapping the indexes using an interpolation technique such as kriging (although even hand contouring may be effective in some areas). Both the map and the individual well indexes are deliverables of this project. The index calculation requires a sequence of logical statements to evaluate the hydrogeological conditions at each well, followed by arithmetic statements to sum up the net susceptibility index at each well. This is achieved conveniently using a programming language such as VB or VBA within a database such as Microsoft Access (although it may also be accomplished with spreadsheet software). Several of the steps will also require a working knowledge of GIS software with interpolation packages. For details, refer to *Schedule A: Required Groundwater and Aquifer Characterization Components with Methodologies*.

**Uncertainty** – In light of the general uncertainty within the data in the WWIS, it is strongly recommended that the groundwater intrinsic susceptibility (GwIS) maps not be used directly for planning purposes without further site specific verification regarding any potential sources of contamination.

**Local Expertise** – Consultants are encouraged to apply local expertise to improve the quality of the mapping product. The Ministry recognizes that elements of the maps, such as water table, are the product of considerable interpretation. Local knowledge of groundwater flow systems, pump tests, geochemistry, soils, topography and other factors could have important effects on vulnerability assessments when taken into account. For the local context the consultant must apply knowledge of local hydrogeologic/geologic conditions, factors and uncertainties in existing databases to enable the best decisions to be made on vulnerability. Only limited procedures are offered in applying decisions in these cases.

Study participants are also encouraged to apply local hydrogeological knowledge and expertise to develop enhanced local scale Groundwater Intrinsic Susceptibility (GwIS) maps for immediate land use planning applications. The mapping procedures are left to the discretion of the funding recipient, but should include locally relevant hydrogeological data and an appreciation for local groundwater flow systems.

**References** – The International Association of Hydrogeologists publication “Guidebook on Mapping Groundwater Vulnerability” (1994, edited by Jaroslav Vrba and Alexander Zaporozec) is recommended as useful reference to further understand founding concepts of aquifer vulnerability mapping, and provide guidance on the use and interpretation of the data types available.

### **2.2.1 Step 1: Data Preparation**

**Geological Descriptions** – The Geological Survey of Canada has developed rules for improving the geological descriptions in the MOE Well Log Database which are presented in *Schedule B*. These revised descriptions will be included in the database provided by the MOE or otherwise made available to grant recipients, and should be used for the GwIS map. A list of the GSC terms is included in *Schedule B* of this document. This step has been shown to improve the quality of the geological descriptions used for the GwIS map.

**Well Selection and Screening** – All wells with a MOE Well Log database universal transverse mercator (UTM) or Elevation Reliability Code error of more than 6 should be initially filtered out of the analysis. The UTM error code refers to the estimated accuracy of the UTM coordinates for the well; a code of 6 implies an error of at least 300 m. Similarly an Elevation Error Code of 6 implies an elevation error of at least 15 metres.

### 2.2.2 Step 2: Water Table

A depth to water table map is a requirement of the groundwater study, and is to be used in the preparation of the GwIS map. The water table depth map should be prepared by interpolating a water table surface based on the static water level depths from shallow wells. The consultant is required to assess the local hydrogeological regime and develop a rationale for selecting 'shallow wells' and other relevant data points for the generation of a water table map. The map will be considered the 'best available' depth to water table surface, and should be updated periodically as new information comes available.

**Database Updates** – The depth to water table is required at all wells in order to calculate the groundwater Intrinsic Susceptibility Index (ISI) at each well. The consultant is therefore required to add the interpolated depth to water table from the map to all wells in the database for the study area.

**Inadequate Or Unreliable Water Table Data** – For each stratigraphic layer, for selected "Effective Thickness" or depth from ground surface, which has been derived from the preliminary data analysis, a K-Factor (see *Schedule C: Generic Representative Permeability (K-Factor) Table*) is estimated and is multiplied by the thickness of that layer. The summed value of the K-Factors is then used to classify whether an area is of High, Medium, or Low Intrinsic Susceptibility to Contamination. This method can be used where it can be justified to the MOE, prior to using the method, that the water table information is inadequate and will lead to misleading or unacceptable uncertainty. The rationale will need to be provided to the MOE, as well as the detailed description of the method. The MOE will decide what areas or parts of areas can be mapped using an alternate method. The "effective thickness" should represent a reasonable surrogate for depth to water table and/or depth to aquifer and should be based on a review of all hydrogeologic information, including the water wells. Histograms of water wells with depth to water table, etc. should be included in the rationale.

### 2.2.3 Step 3: Calculation of Intrinsic Susceptibility Index (ISI) at Each Well

The preparation of the GwIS map includes calculation of an intrinsic susceptibility index (ISI) for each well. This value is written to the database and used to prepare the final map.

The ISI is calculated by summing the product of the thickness of each unit in the well log and a corresponding K-Factor. The K-Factor (reference table provided in *Schedule C*) is a dimensionless, relative number that can be loosely related to the exponent of the vertical hydraulic conductivity in m/s. The calculation is performed from surface to a lower limit defined by the water table configuration.

The consultant shall assess the geology at each well, distinguishing aquifers from aquitards to properly account for consecutive layers of similar materials.

The consultant shall determine on a well-by-well basis if the aquifer of interest is confined, semi-confined or unconfined. The regional groundwater intrinsic susceptibility (GwIS) map is focused on evaluating the uppermost 'significant' aquifer (to be determined by the consultant and the local study team), and considering:

- the use of the aquifer as a drinking water source;
- the linkage of the uppermost aquifer to any local surface water systems and the sensitivity of these systems; and
- the linkage the aquifer might have to deeper aquifers that are used for drinking water.

**Confined Aquifers** – For confined aquifers, it is reasonable to assume that contaminants from the surface must migrate through the confining layer and reach the aquifer to cause potential impact. Therefore, the ISI is calculated by summing the product of the thickness of each geological unit in the well and the corresponding K-Factor (refer to *Schedule C*), from ground surface to the top of the first significant aquifer.

**Unconfined Aquifers** – For unconfined aquifers, it is reasonable to assume that contaminants from the surface must only migrate to the water table to cause potential impact. Therefore, the ISI is calculated by summing the product of the thickness of each geological unit in the well and the corresponding K-Factor, from ground surface to the water table.

**Semi-confined Aquifers** – For semi-confined aquifers or where there is doubt about the integrity of the confining layer, it is reasonable to assume that contaminants from surface must migrate through a leaky layer and reach the aquifer to cause potential impact. Expert judgement is needed to evaluate the hydrogeological and hydrological information collected for the groundwater studies. Determining if a field of wells should have a modified K-Factor should be based on best professional judgement. The ISI is calculated by summing the product of the thickness of each geological unit in the well and an appropriate K-Factor (refer to *Schedule C*), from ground surface to the top of the water table.

**Missing Aquifers** – For wells where no aquifer material is detected, based on the codes provided in *Schedule B*, the ISI will be calculated as the sum of the product of the unit thickness and the K-Factor from the ground surface to 15 metres below the ground surface.

**Data Reliability Issues** – Where the data and well density are too low to confidently produce the mapping of the water table and geologic materials an alternate method must be proposed which is as faithful as possible to the MOE suggested method. Unreliable wells can be screened out.

Adjustments might also be appropriate where it is clear that certain information sources consistently misrepresent a geological feature of significance. The methods used must be clearly documented for dealing with data reliability issues and interpolation methods between water wells. Adjustments may be used as they arise during the derivation of enhanced local groundwater intrinsic susceptibility maps through the use of local expertise.

**Definitions** – The specific definitions of the first “significant” aquifer and what qualifies as a semi-confined aquifer, confined aquifer will be defined by the consultant in the context of local hydrogeological conditions.

#### **2.2.4 Step 4: Categorizing Intrinsic Susceptibility Index (ISI) Values**

For final mapping purposes, the ISI value at each well is categorized into Low (<30), Medium (30 to 80), and High (>80) groupings. The thresholds defining the limits of these categories will be established by the consultant to best reflect local hydrogeological resources and functions.

Once the initial classification has been applied and shown on a preliminary map, the classification limits may be adjusted to reflect local conditions by the consultant to produce the final derived map. The threshold rationale must be clearly described and justified, and account not only for water supply aquifers, but also the ecosystem functions as related to wetlands, rivers, etc..

### **2.2.5 Step 5: Mapping**

The final map is developed by interpolating the categorized ISI values at each well. Although the selection of an interpolation method shall be at the discretion of the consultant, a kriging algorithm is recommended, using a grid cell size of 500m or less with a preference for a lower grid spacing.

**Boundary Harmonization** – Consultants must identify how boundary issues with adjoining municipalities will be harmonized. Adjacent study areas must work together for the harmonization of the thresholds where they have been modified from the original classification. Harmonization issues include: geomaterial coding, water table and confined or unconfined aquifer definitions, and intrinsic susceptibility evaluations. The MOE may provide ground rules on harmonization where there are circumstances of unresolvable harmonization of threshold tiers.

#### **Intrinsic Susceptibility Thresholds –**

- Low intrinsic susceptibility values will be greater than 80;
- Low to moderate intrinsic susceptibility values will be between 30 and 80; and
- High intrinsic susceptibility values will be less than 30.

## Schedule B

### GSC Geomaterial Protocol

There is a need to standardize the descriptions of subsurface material as reported in water well and other borehole data. We recommend that the Geological Survey of Canada (GSC) Geomaterial Protocol be used to help build improved municipal hydrogeological data sets for further analysis and interpretation.

The GSC Geomaterial Protocol provides the basis for a standardized approach to material descriptions for all borehole information used in a groundwater study. The protocol is best applied at the outset of a project and directly to borehole data sets received from various agencies. The coding routine is best used within a relational database structure (e.g. SiteFx software). Use of a relational database facilitates the standardizing of a large number of boreholes and information such as the 212 fields in the MOE water well records.

The coding protocol was developed by geologists who re-coded material descriptions found in provincial water well records. The records allow for the use of three fields for drillers to enter material descriptions; however, only one field was used in most records. To partly compensate for this problem, the geologists linked re-coding rules to the many thousands of field sites they observed during geological mapping studies. In 1998, the GSC published the results of their extensive testing program as part of database developed through the Oak Ridges Moraine Hydrogeology Project. One conclusion of the re-coding and field testing was that the "clay" descriptions are over represented compared to their occurrence in the field, by a factor of 10. This is a significant finding because "clay" material is often used as a key factor in determining groundwater vulnerability.

A description of the geomaterial protocol to be used in municipal groundwater studies funded by the province is found in the following reference:

**Standardization and assessment of geological descriptions from water well records: Greater Toronto and Oak Ridges Moraine Areas, southern Ontario**, Russell, H. A. J., Brennand, T. A., Logan, C., and Sharpe, D. R., 1998, Current Research 1998-E: Ottawa, Geological Survey of Canada, p. 89-102.

The Ontario Ministries of the Environment, Natural Resources, Mines and Northern Development contribution have been acknowledged in the reference. The reference is available through the internet site at: [http://sts.gsc.nrcan.gc.ca/orm/acrobat\\_data.asp](http://sts.gsc.nrcan.gc.ca/orm/acrobat_data.asp).

The abstract and tables 1, 3 4. and 5 are presented here, followed by the suggested method for documenting the Metadata for the GSC Geomaterial Protocol.

#### Abstract

Archival drilling records from water wells, geotechnical, mineral exploration, and hydrogeologic studies provide subsurface information for regional geologic and hydrogeologic investigations. This paper evaluates methods by which water well material descriptions may be standardized. In Ontario, material descriptions are reported in three attribute fields using 82 terms, thus theoretically permitting over 500,000 permutations. Materials descriptions are rationalized to 10 classes then reclassified according to two methods: (i) First-Attribute Method (FAM), and (ii) Rule-Based Method (RBM). The first-attribute method is presently applied by hydrogeologists in southern Ontario and uses only the first attribute field; it is a simple, effective method able to broadly delimit aquifers and non-aquifers. The rule-based method applies conditional rules developed from regional geologic models. This method is more geologically accurate, and is recommended where water well data are to be integrated into geologic and hydrogeologic investigations. Successful applications are summarized and general recommendations made.



## Schedule B (continued)

Header	Geology	Hydrogeology	
Well Number (2)	Unit - Depth to Top (24)	Piezometer Indicator (1)	Casings (18)
Municipality (2)	Unit - Colour (24)	Water - Depth Found (5)	Screens (8)
Concession – Range (4)	Unit - Materials (3x24)	Water - Kind (5)	Plugs (6)
Lot (2)		Test Method (1)	
Owner (1)		Pumping (2)	
Completion Date (3)		Levels (2)	
UTM Location (4)		Pumping/Recovery Indicator (1)	
Elevation (2)		Level During Pumping (4)	
Basin (5)		Flow Rate (1)	
Water Use (2)		Clear - Cloudy (1)	
Drill Method (1)		Recommended Setting (1)	
Data Source (1)		Recommended Rate (1)	
Contractor Code (1)		Specific Capacity (1)	
Date Received (3)		Final Status (1)	

## Schedule B (continued)

Table 3 - Rationalized Descriptors for MOE WWIS. (%- usage in all 3 materials data fields)		
Rationalized Descriptor	MOE Dataset Descriptor	
1 bedrock (0.1%)	18 sandstone 20 quartzite 21 granite 22 greenstone 26 rock (bedrock) 36 basalt 37 chert 38 conglomerate 39 feldspar	40 flint 41 gneiss 42 greywacke 43 gypsum 44 iron fm. 45 marble 46 quartz 47 schist 48 soapstone
1.1 limestone (0.8%)	15 limestone	16 dolostone
1.2 shale (0.9%)	17 shale 19 slate	82 shaly
2 gravel (9.7%)	11 gravel 12 stones 13 boulders 29 fine gravel 30 medium gravel	31 coarse gravel 32 pea gravel 72 gravelly 87 stoney
3 sand (12.3%)	7 quicksand 8 fine sand 9 medium sand	10 coarse sand 28 sand 81 sandy
4 silt (1.5%)	6 silt	84 silty
5 clay (16.1%)	5 clay	61 clayey
6 diamicton (0.5%)	14 hardpan	34 till
7 organic (0.1%)	3 muck 4 peat	33 marl 35 wood frags.
8 fill (3.7%)	1 fill 2 topsoil	25 overburden
9 previously dug (0.7%)	0 unknown 23 previously bored	24 previously drilled
99 null (53.6%)	27 -	

## Schedule B (continued)

Table 4: Geologic Descriptions and Usage - example : ORM	
Geologic Description	Usage %
99 no obvious material code	0.15
11 covered; missing; previously bored	0
10 fill (incl. topsoil, waste)	13.29
9 organic	0.15
8 clay, silty clay	21.21
7 silt, sandy silt, clayey silt	2.52
6 sand, silty sand	28.68
5 gravel, gravelly sand	14.89
4 clay-clayey silt diamicton	0.22
4-1 clay-clayey silt diamicton, stoney	
3 silt-sandy silt diamicton	13.90
3-1 silt-sandy silt diamicton, stoney	
3-3 diamicton, texture unknown	
2 silty sand-sand diamicton	0.41
2-1 silty sand-sand diamicton, stoney	
1 bedrock	4.58
1-1 limestone	
1-2 shale	
1-4 dolomite	
1-5 potential bedrock	
1-7 interbedded limestone/shale	

Examples of geological reclassifications based on the application of conditional rules presented in Table 5

Descriptor 1	Descriptor 2	Descriptor 3	
Bedrock			Bedrock (1)
Clay	Gravel		Silt diamicton (3)
Silt	Shale		Shale (1-2)
gravel	sand		Gravel (5)

## Schedule B (continued)

### General Process for Applying the GSC Geomaterials Protocols to a Borehole Database

#### MAIN STEPS

##### I. Simplify Descriptor Strings:

- I.1. If organic has an accompanying descriptor, then organic is treated as null (see I.5).
- I.2. If clay occurs with sand or gravel, then clay is treated as silt.
- I.3. If bedrock descriptor is not for the last unit of the well or not with continuous bedrock beneath, then bedrock is treated as gravel.
- I.4. If clay or silt is with shale, then clay and/or silt is treated as null (see I.5).
- I.5. Remove duplicate attributes and spaces; eliminate all leading null fields.

##### II. Apply Global Rules

- II.1. If a single descriptor, then the description is based directly on that descriptor (see Table 4).
- II.2. If till in any field, then treat as diamicton (see Subroutine A below).
- II.3. If gravel is in any field with no bedrock and clay is not first descriptor, then treat as gravel.
- II.4. If fill and previously dug in any field are without bedrock, then treat as fill; else with bedrock, then treat as potential bedrock.
- II.5. If all fields are null, then treat as no obvious material code.
- II.6. If previously dug or fill are in any field except with bedrock, then treat as fill.

##### III. Apply Bedrock Rules

(Apply if last unit in well or if continuous bedrock beneath)

- III.1. < 5 m depth, bedrock anywhere then code = bedrock (see Subroutine B below for categories)
- III.2. > 5 m depth, bedrock anywhere and gravel anywhere then code = gravel
- III.3. > 5 m depth, bedrock anywhere and sand/silt/clay and no gravel then code = diamicton (see Subroutine A below)

##### IV. Apply Sediment Texture Rules

- IV.1. Attribute 1 = sand with attribute 2/3 = silt or clay and no gravel, then treat as sand
- IV.2. Attribute 1 = silt with attribute 2/3 = sand or clay and no gravel, then treat as silt
- IV.3. Attribute 1 = clay with attribute 2/3 = sand or silt and no gravel, then treat as silt

#### SUBROUTINES

##### Subroutine A: Determine Diamicton Texture

(Use textural sand-silt-clay attribute in highest attribute position)

1. If sand, then treat as silty sand diamicton
2. If silt, then treat as silt diamicton
3. If clay, then treat as clay silt diamicton
4. If no texture indicated, then treat as silt diamicton

##### Subroutine B: Determine Bedrock Lithology

1. If bedrock in any field and not with limestone or shale, then treat as bedrock
2. If limestone in any field and not with shale, then reclassify as limestone
3. If shale in any field and not with limestone, then reclassify as shale
4. If limestone and shale in any field, then reclassify as interbedded limestone - shale

## Schedule C

Generic Representative Permeability (K-Factor) Table

Geomaterial	Representative K-Factor (dimensionless)*	K-Value (m/s) @75% range**	Highest K-Value (m/s)
gravel weathered dolomite/limestone karst permeable basalt	1	1.00E-01 1.00E-06 1.00E-03 1.00E-03	0.1
sand	2	0.01	1.00E-02
peat (organics) silty sand weathered clay (<5m below surface) shrinking/fractured & aggregated clay fractured igneous metamorphic rock weathered shale	3	1.00E-03 1.00E-04 1.00E-04*** 1.00E-04*** 1.00E-05 1.00E-05***	1.00E-03
Silt loess limestone/dolomite	4	1.00E-06 1.00E-06 1.00E-06	1.00E-06
weathered/fractured till diamicton (sandy, silty) diamicton (silty, clayey) sandstone	5	1.00E-07 1.00E-07*** 1.00E-08*** 1.00E-07	1.00E-07
clay till clay (unweathered marine)	8	1.00E-09*** 1.00E-10	1.00E-09
unfractured igneous and metamorphic rock	9	1.00E-13	1.00E-13

\* Representative K-Factors are relative numbers and do not correspond directly to the exponent or index of the observed K-Values for the geomaterial in the group.

\*\* Correspondence with descriptors of observed K-Values in Freeze & Cherry 1979, Prentice-Hall. Derived using the length of the line to determine the 75% value and rounding to the highest K-Value.

\*\*\* Estimated value based on field studies in Ontario

*NOTE: When actual study area data is available, this chart should be used to assign the corresponding K-Values for locally defined geomaterial (e.g., Mayhill Till) and then apply the appropriate Representative K-Factor in the calculation of the index of the groundwater intrinsic susceptibility to contamination.*