

GUIDE TO GROUNDWATER WITHDRAWAL APPROVALS

July 2013

“One must, however, note that the flow does not always remain the same. Thus when there are rains the flow is increased, for the water on the hills being in excess is more violently squeezed out. But in times of dryness the flow subsides because no additional supply of water comes into the spring. In the case of the best springs, however the amount of flow does not contract very much . . . It is also necessary to find the speed of the flow, for the swifter the flow the more water the spring delivers, and the slower it is, the less.”

Dioptra, Hero of Alexandria (ca. A.D. 65)

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1. Background Information.....	1
1.2. Water Use Licensing.....	1
1.3. Approach to Licensing Groundwater Allocations	2
1.4. Intended Audience	5
1.5. Acknowledgements.....	5
1.6. Structure of this Document.....	5
2. HYDROGEOLOGICAL STUDY REQUIREMENTS	6
2.1. Description of Site and Water Supply Details	6
2.1.1. <i>Site Description</i>	6
2.1.2. <i>Proponent Well Field Description</i>	6
2.1.3. <i>Description of Intended Water Use</i>	6
2.1.4. <i>Description of Proposed Groundwater Withdrawal</i>	7
2.1.5. <i>Description of Existing Groundwater Withdrawal Approvals</i>	7
2.2. Description of Hydrogeology	7
2.2.1. <i>Local Geological Setting</i>	7
2.2.2. <i>Site Hydrogeology</i>	7
2.3. Pump Test Information	8
2.3.1. <i>Pump Test Design</i>	8
2.3.2. <i>Pump Test Analysis</i>	9
2.3.3. <i>Water Quality Analysis</i>	10
2.4. Evaluation of Potential Effects	12
2.4.1. <i>Permissible Withdrawal Limits</i>	12
2.4.2. <i>Third Party Interference</i>	12
2.4.3. <i>Water Quality</i>	13
2.4.4. <i>Groundwater-Surface Water Interaction</i>	13
2.4.5. <i>Other Considerations</i>	13
2.5. Meeting Other Regulatory and Permitting Processes	13
2.6. Monitoring and Contingency Plans	14
2.6.1. <i>Monitoring Plan</i>	14
2.6.2. <i>Contingency Plan</i>	14
2.6.3. <i>Other Requirements</i>	14
2.7. Additional Information	15
2.7.1. <i>Survey of Neighbouring Wells</i>	15
2.7.2. <i>Supporting Data and Figures</i>	15
2.7.3. <i>Water Well Complaints</i>	16
3. ADDITIONAL REFERENCES	17
4. APPENDIX A: SUBMISSION CHECKLIST	18
5. APPENDIX B: PUMP TEST DESIGN.....	19

LIST OF FIGURES

Figure 1: Licensing Thresholds for Various Usage Categories 2
Figure 2: Process for a Greenfields Project 3

LIST OF TABLES

Table 1: Monitoring Frequency 9
Table 2: Determining Water Quality Parameters to be Investigated 11
Table 3: Submission Checklist for Hydrogeological Studies 18
Table 4: Design of Pump Test for the Anticipate Annual Diversion..... 19

GLOSSARY

Aquifer – An underground layer of water-bearing permeable rock or unconsolidated materials (silt, sand, gravel) from which groundwater can be extracted using a water well. [Note: The term “underground aquifer” is largely redundant.]

Aquifer, confined – An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, semi-confined – An aquifer confined by a lower permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a *leaky artesian* or *leaky confined aquifer*.

Aquifer, unconfined – An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table represents the top of the aquifer. *Water-table aquifer* is a synonym.

Beneficial use – Used to establish the limit of the administrative right based on the water required to accomplish a stated purpose.

Confining bed – A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer.

Drawdown – A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of groundwater from wells.

Greenfields project – A project lacking in any constraints imposed by prior work.

Groundwater – The water located beneath the earth’s surface in soil pore spaces and in fractures of rock formations.

Groundwater flow – The movement of water through openings in sediment and rock; occurs in the zone of saturation.

Hydrogeology – The study of the interrelationships of geologic materials and processes with water, especially groundwater.

Hydraulic conductivity – A coefficient of proportionality describing the rate at which water can move through a permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity.

Hydraulic gradient – The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Hydraulic, total head – The sum of the elevation head, the pressure head, and the velocity head at a given point in an aquifer.

Observation well – A non-pumping well used to observe the elevation of the water table or the potentiometric surface. An observation well is generally of larger diameter than a piezometer and typically is screened or slotted throughout the thickness of the aquifer.

Permissible withdrawal – The amount of naturally occurring groundwater that can be economically and legally withdrawn from an aquifer on a sustained basis without impairing the native groundwater quality or creating an undesirable effect such as environmental damage.

Prior appropriation – Prior Appropriation is guided by a “first-in-time, first-in right” principle that determines seniority among licensees. Each licensee has similar rights against subsequent licensees, and seniority is enforced, if necessary, by shutting down the works of licensees in reverse order of application date. For the purposes of this document, prior appropriation refers to statutory law where the rights depend upon the grant of licence by the Crown as opposed to the common law where rights depend upon the date at which water is first put to use. Also known as *Prior Allocation*.

Priority of purpose – The order is defined as follows: domestic, municipal, agricultural, industrial, irrigation, and other purposes. Where the date of submission is identical, applications have precedence in relation to one another according to the priority of purpose.

Pumping test – A test conducted by pumping a well for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer.

Specific capacity – An expression of the productivity of a well, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time the drawdown measurement is made. It will generally decrease with time as the drawdown increases.

Specific yield – The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take months to occur.

Storativity – The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer storativity is equivalent to the specific yield. It is also called the *Storage Coefficient*.

Transmissivity – The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of the properties of the liquid, the porous media, and the thickness of the porous media.

Water budget – An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or drainage basin.

Well log – A record of the lithology of the rock and soil encountered in a borehole from the surface to the bottom.

Well, fully penetrating – A well drilled to the bottom of an aquifer, constructed in such a way that it withdraws water from the entire thickness of the aquifer.

Well, partially penetrating – A well constructed in such a way that it draws water directly from a fractional part of the total thickness of the aquifer. The fractional part may be located at the top or the bottom or anywhere in between in the aquifer.

1. INTRODUCTION

1.1. Background Information

The diversion and use of surface water in Manitoba was originally regulated by the federal *Northwest Irrigation Act* of 1894 and later by the provincial *Water Rights Act* of 1930. The *Northwest Irrigation Act* introduced a water rights system similar that to that in use in Australia and western United States in that it was based on the principles of prior appropriation or “first in time, first in right”. All of these schemes were concerned with the fair and equitable allocation of water in a dry climate. The diversion and use of groundwater in Manitoba was first regulated in 1959 when the provincial *Water Rights Act* was amended to include groundwater in the definition of the types of water.

Since 2004, almost all applicants proposing a new use of groundwater have been required to hire a qualified hydrogeologist. For the purposes of this guideline, a “qualified hydrogeologist” is a person with hydrogeology training and experience, and licensed to practice in Manitoba by the Association of Professional Engineers and Geoscientists of Manitoba (APEGM). The “qualified hydrogeologist” must sign and stamp a report in support of the application which is to be submitted to the Department in electronic format and hard copy.

1.2. Water Use Licensing

Water Use Licensing is the principal mechanism for achieving the sustainable development of Manitoba’s water resources. It is more formally known as Water Rights Licensing. Drainage licensing is also administered under the provisions of *The Water Rights Act* but drainage licensing is not discussed in this guideline. The allocation of the province’s water resources for hydroelectric generation is administered under *The Water Power Act*.

A “Water Use Licence” is generally required for taking water from surface water sources and aquifers for municipal, industrial or other purposes and for agricultural and irrigation purposes where the quantity exceeds the threshold of 25,000 litres per day. Figure 1 outlines the licensing thresholds for various water use purposes defined under *The Water Rights Act*: municipal; agricultural; industrial; irrigation; and other purposes. Examples of licences issued under the other purposes category include commercial facilities like rural car and truck washes and recreational facilities like water slides.

Abstraction licenses are issued for a specific term not exceeding 20 years in duration. Most municipal licences are issued for 20 years whereas licences issued for non-municipal purposes are frequently issued for 10 years or less. Upon licence expiry, a licensee may apply for a renewal of the licence subject to demonstrating a continuing need for the abstracted water. The reporting requirements are commensurate with the scale and complexity of the water use.

An abstraction licence can also be transferred during the term of the licence. Generally this occurs when the business is sold to a new owner. For instance, if a hog barn or irrigation

project is sold “as a going concern” the associated licence may be transferred upon application by the new owner. Such transfers are relatively straight forward to process as in many cases there is no change to either the point of diversion (POD) or point of use (POU). Although *The Water Rights Act* anticipates the transfer of water from one use purpose to another use purpose, such transfers have been rare to date. Note: If the licensee is a corporation, it is often unnecessary for a transfer application to be made upon change of ownership of the corporation. Generally, under these circumstances, the Department requires only that the new owners update the Department with their contact information.

The abstraction licensing scheme in Manitoba is based on traditional risk management principles. This will become evident in the remaining sections of this guideline.

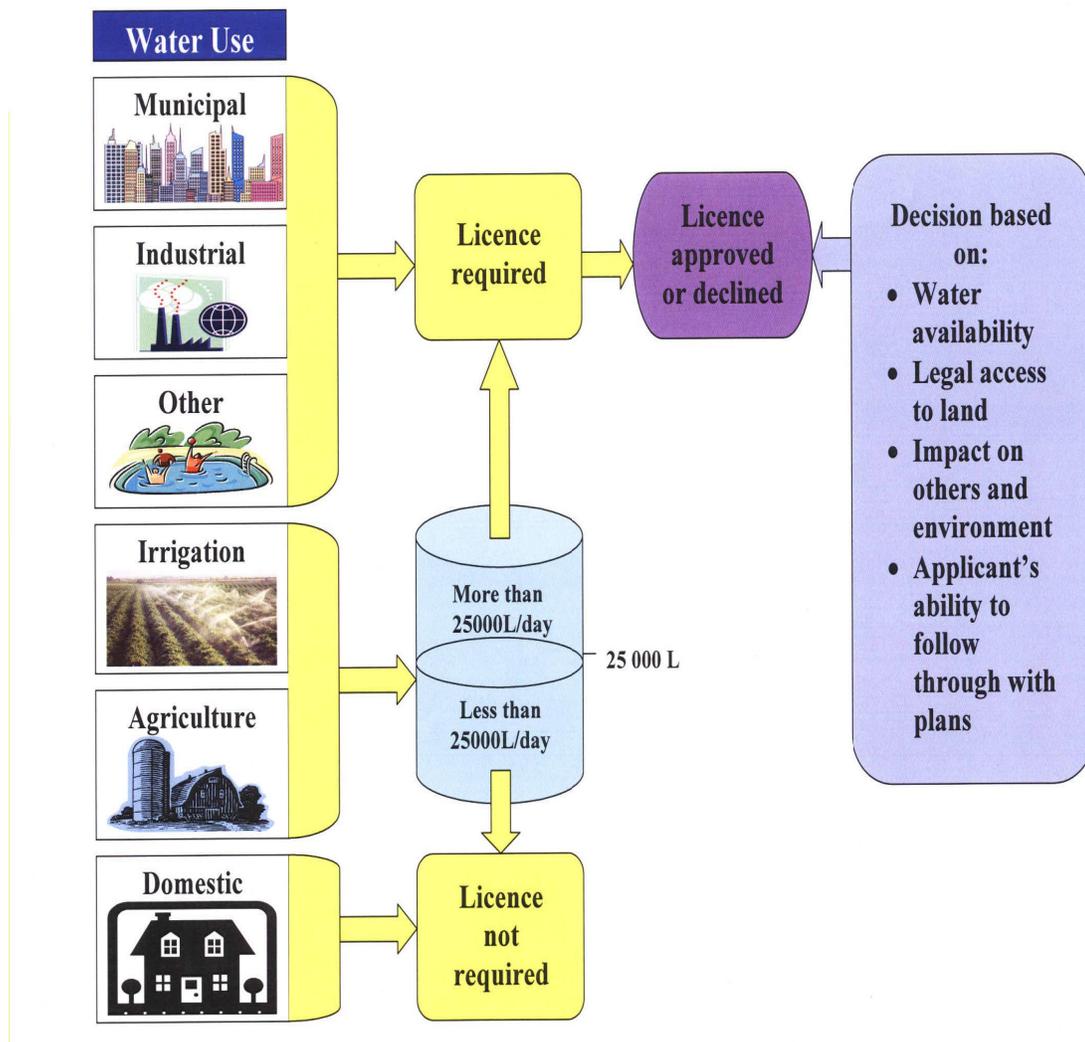


Figure 1: Licensing Thresholds for Various Usage Categories

1.3. Approach to Licensing Groundwater Allocations

Before the consultant initiates a technical investigation in support of the issuance of a Permit or Licence issued under the authority of *The Water Rights Act*, it is imperative that the consultant and their client understand the general outline of the regulatory process. It must be kept in mind from the outset that although the technical information presented in the consultant’s report is often essential to the decision to issue a Permit or Licence, the process remains administrative in design. As such difficult or unresolved technical issues are often addressed by conditioning any licence issued to the proponent. Figure 2 illustrates the process for a “Greenfields” project.

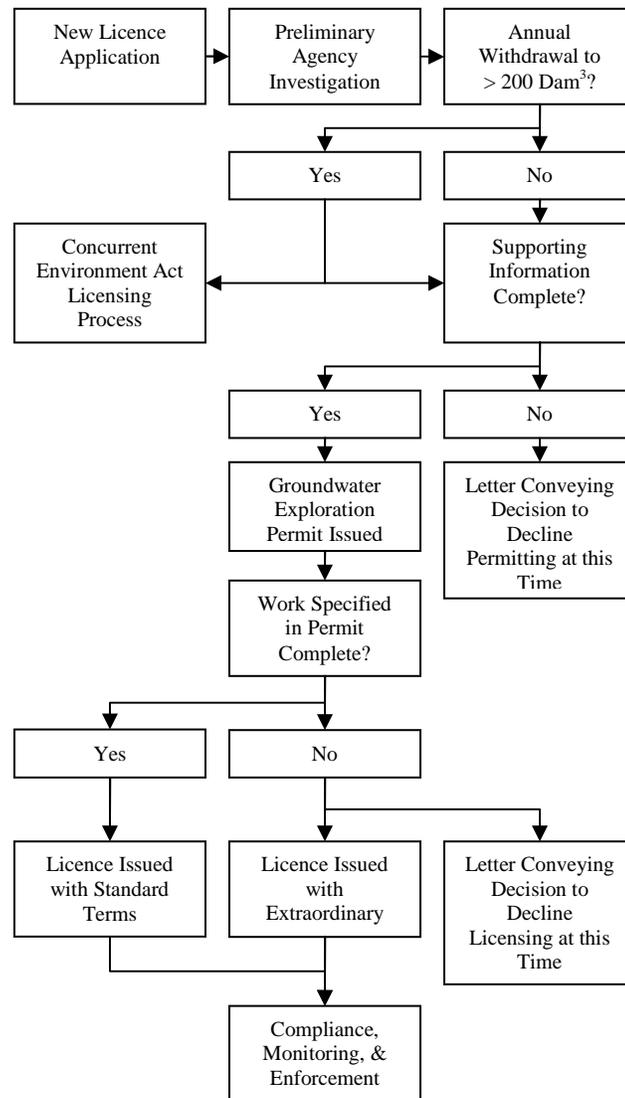


Figure 2: Process for a Greenfields Project

The following guiding principles are used in allocating groundwater resources:

- (1) Does the proposed use/change conflict with other existing water rights?

To answer this question, the applicant must demonstrate what the impact of the proposed withdrawal may have on nearby senior rights holders. A desktop and/or field survey of nearby licensed wells must be completed. The radius of the well inventory will vary with the proposed pumping rate and total annual abstractions and aquifer conditions (including transmissivity and storativity / specific yield of aquifer). The determination of well specific capacities can also be a useful tool for assessing impacts.

(2) Does the use/change conflict with protectable interests in existing domestic wells?

To answer this question, the applicant must demonstrate what the impact of the proposed withdrawal may have on nearby established domestic wells. A desktop and/or field survey of nearby domestic wells must be completed. The radius of the well inventory will vary with the proposed pumping rate and total annual abstractions and aquifer conditions (including transmissivity and storativity / specific yield of aquifer). The determination of well specific capacities can also be a useful tool for assessing impacts.

(3) Is the project as proposed in the public interest?

To answer this question, the applicant must consider whether their project falls within one of the named beneficial usage categories (municipal, agricultural, industrial, irrigation) or if it falls within the catch all usage category “other”. If the usage falls within the “other” category (rural car/truck wash, recreational facility, air heating and/or cooling, construction dewatering, etc.), the applicant should describe the project in greater detail than normally warranted to demonstrate beneficial use of the resource.

(4) Is there unappropriated water at the proposed source?

To answer this question, the applicant must consider whether the aquifer proposed for development has an established permissible withdrawal limit assigned to it. If so, the applicant must further consider whether there is sufficient remaining allocation for the project as proposed. If the aquifer proposed for development does not have an established permissible withdrawal assigned to it, the applicant must consider whether any long term groundwater level declines, water quantity decreases to discharge features, and/or water quality changes as a result of induced recharge have been observed locally and/or regionally.

(5) Is there a credible threat of serious or irreversible ecological damage?

To answer this question, the applicant must consider from a water quantity standpoint whether the potential exists for a permanent decline of hydraulic head in the aquifer and from a water quality standpoint whether water quality changes would also be permanent.

(6) Is there reasonable expectation that the applicant plans to construct the works and apply the water to the intended beneficial use with reasonable diligence?

To answer this question, the applicant must consider whether the requested withdrawal amounts to speculation in water. The request could be considered speculative if the existing or proposed works lacked the capacity to deliver the requested withdrawal and/or if the applicant fails to apply the requested quantities within the expected licence term. The latter issue can sometimes be addressed by requesting that the proponent prepare and submit a simple business plan demonstrating the need for the water and projected project

time lines. The agency, for example, requests all submissions for irrigation water to include an Irrigation Project Questionnaire (IPQ). The section can assist the proponent in the preparation of an IPQ or other such “business plan”.

1.4. Intended Audience

The intended audience of this guideline is the consulting hydrogeologist preparing a report in support of a water rights application for the first time or preparing a report in support of a water rights application larger in scope than previous submissions. The water rights licensing process is a venerable regulatory scheme and, therefore, this document is not intended to capture all nuances of the guiding doctrine but rather is intended to provide the reader with sufficient advice to avoid a “textbook” approach. It is anticipated and ever expected that consultants will use their professional judgement.

It is acknowledged that other audiences such as proponents, environmental non-governmental agencies, other provincial and federal regulators, etc. may take an interest in this guideline. Such interest is encouraged and should prove useful. For example, proponents may find the document useful in defining the terms of a tender. However, a word of caution is also warranted. No document can be all things to all people. For example, proponents cannot be guaranteed that a water rights licence will be issued even if all the steps of the guideline are followed.

1.5. Acknowledgements

The authors of this document were informed by exposure to a vast literature on the topic from other parts of North America as well as the United Kingdom and Australia in addition to our own experience with licensing and re-licensing hundreds of projects. The basic structure of the document was fashioned after the “Guide to Groundwater Withdrawal Approvals, October 2010”, Nova Scotia Environment with some influence after the “Guide to Groundwater Authorization” Alberta Environment.

1.6. Structure of this Document

The remainder of this document is structured as follows:

- Section 2 describes the requirements of a hydrogeological investigation conducted in support of an application for a water rights licence.
- Section 3 lists some additional references.
- Appendices include relevant check lists and tables.

2. HYDROGEOLOGICAL STUDY REQUIREMENTS

The hydrogeological study typically includes the information summarized in the following sections. A submission check list of the minimum general requirements of a hydrogeological study is presented in Appendix A. The checklist in Appendix A must be completed and submitted with the hydrogeological study. The hydrogeological study is to be submitted to the Department in electronic format and hard copy. It is also important to keep in mind that the regulatory decision to be made under *The Water Rights Act* concerns the allocation of the resource. However, depending on the project, the hydrogeological study may also be used to meet the requirements of other regulatory processes.

Applicants are encouraged to contact the Water Use Licensing Section upfront to discuss licensing requirements. As stated near the beginning of this guide, the scheme of *The Water Rights Act* is compatible with a risk assessment and risk management approach.

2.1. Description of Site and Water Supply Details

2.1.1. Site Description

A description and diagram of the site including: proposed point of diversion (POD), proposed point of use (POU), and a description of legal access to the POD and POU (i.e. land title certificate, lease agreement, rental agreement, etc.).

For a public or semi-public water system, a description on how site selection dealt with potential contamination risks may prove useful to third party readers and other regulators.

2.1.2. Proponent Well Field Description

The location and a description of all the wells in the well field including: well log details, PID number, geographical coordinates (UTM - NAD83) of all wells in the well field, wellhead completion, water use records, water levels and history of any well interference or other concerns. The PID number can be obtained from the provincial groundwater database GWDriill. If a well log cannot be obtained, well construction details may be obtained by other means (i.e. well inspection with a camera) when and if required.

For a public or semi-public water supply system, a description on how well construction dealt with potential contamination risks may prove useful to third party readers.

2.1.3. Description of Intended Water Use

A description of the intended use of the water – agricultural (i.e. livestock), industrial, irrigation, municipal, or other (i.e. air cooling and/or heating, recreation, etc.) - and water requirements. If the application relates to a renewal, transfer, and/or amendment of an existing water approval, the reason for the change (if any) should be discussed (i.e. company sold, land sold, project expansion, etc.).

Current water needs should be presented separately from projected water needs. Projected water needs will generally only be considered for municipal projects. Projected water needs should fall within a 20 year period for municipal usage. If a proponent's water use exceeds the licensed annual allocation, a request to amend the approval should be made.

2.1.4. Description of Proposed Groundwater Withdrawal

For all wells in the well field, details must be provided regarding the proposed groundwater withdrawal including: maximum instantaneous withdrawal rate (i.e. pump and pipeline capacity), annual withdrawal volume (i.e. average daily pumping rate multiplied by number of days pumped, and seasonality of diversion (i.e. months of year to which withdrawal applies).

The maximum pumping rate requested cannot exceed the rate used during the constant rate pumping test.

2.1.5. Description of Existing Groundwater Withdrawal Approvals

A description of existing and previous approvals related to the project point of diversion (POD) (i.e. water rights licence, temporary authorization, etc.) as well as any history of complaints and/or problems with well interference are/is required.

The report should clarify if any new wells are replacement and/or supplementary wells. A replacement water well is a new well constructed to replace an existing well (e.g. constructed in the same property as the original well, completed in the same aquifer as the original well, etc.) and the original well must be decommissioned in accordance with *The Groundwater and Water Well Act*. A supplementary well is a well drilled in addition to an existing well. If an additional quantity of water (operational expansion) is needed at the time of drilling the supplementary well, the proponent will be required to apply for a new licence and additional testing may be required.

2.2. Description of Hydrogeology

2.2.1. Local Geological Setting

The report should provide a description of local bedrock and/or surficial geology, including, but not limited to the extent of the water bearing unit. In some instances the internal and structural character of the unit will need to be described.

2.2.2. Site Hydrogeology

A description of local water bearing units based on available well logs and other readily available information sources (e.g. government maps and reports), including, but not

limited to: aquifer type, identification of hydrostratigraphic units, and the hydraulic characteristics of each unit, the degree of hydraulic communication and discussion of the overall groundwater quality. In some instances hydraulic characteristics of each unit (e.g. hydraulic conductivity, transmissivity, storativity / specific capacity, hydraulic head and the seasonal fluctuations, vertical and horizontal hydraulic gradients, groundwater flow direction, boundary conditions, recharge, discharge, and discussion of the overall groundwater quality) will need to be described. Local and/or traditional knowledge, such as the location of springs, may also be incorporated.

2.3. Pump Test Information

The design and analysis of the pump test, in addition to whatever water quality analysis is undertaken, should all be driven from a point of view of ‘what technical information is required to support the decision to issue a licence’ and specifically to answer the six fundamental questions identified in Section 1.3.

2.3.1. Pump Test Design

Appendix B provides typically recommended durations of pumping and recovery tests plus the number of observation wells commonly supporting a groundwater withdrawal application. However, site specific requirements will be outlined at the groundwater exploration permit stage (refer back to figure 2) and the consulting hydrogeologist is expected to exercise their professional judgement in consultation with the Department.

For public and semi public municipal systems or other water supply systems in which several wells will be pumped simultaneously during normal operation, a multiple well test with observation wells may be required in addition to individual well tests. If multiple wells are used, water levels should be corrected to a common geodetic elevation.

A pumping test should be conducted by a licensed well driller under the supervision of the consulting hydrogeologist or by the proponent under supervision of the consulting hydrogeologist. An initial step drawdown test may be required in order to determine the optimum constant rate for the pumping test. A step drawdown test affords a good opportunity to provide a benchmark against which future step drawdown tests (to access well capacity changes) may be compared. The flow rate for the constant rate test must be equal to or greater than the requested withdrawal rate proposed for the licence. During the pumping test, the discharged water must be diverted away from the wellhead to prevent artificial recharge of the aquifer. There may also be a requirement for the responsible parties (ie. proponent, consultant, driller) to inform the local drainage officer and/or municipal office of the planned discharge to a local ditch or drain.

Static water level measurements should be monitored for at least half hour prior to the start of the pumping test in order to obtain background static water levels and conditions. Water level readings measured in the production well(s) and observation well(s) shall be recorded to the nearest 0.5 cm or better during the pumping test. Table 1 presents the recommended schedule for reading frequency; however, it is further recommended that

pressure transducers be used to monitor water level change with manual measurements as backup. Finally, it is recommended that barometric pressure be monitored and that water level readings are corrected for barometric pressure.

From 0 to 10 minutes	Every minute
From 10 to 20 minutes	Every 2 minutes
From 20 to 60 minutes	Every 5 minutes
From 1 to 2 hours	Every 10 minutes
From 2 to 4 hours	Every 15 minutes
From 4 to 8 hours	Every 30 minutes
From 8 hours to end of test	Every 60 minutes

Table 1: Monitoring Frequency

After the pump(s) is turned off, water levels in the pumped well(s) and observation well(s) must be measured while groundwater levels recover. Recovery measurements are to be taken for at least the same length of time as the pumping test, or until the water level has recovered within 90% of pre-testing water level conditions, or whichever comes first. The frequency of recover measurements should be the same as Table 1.

Observation well(s) are to be completed in the same aquifer as the production well(s). Observation wells are often constructed specifically for the pumping test. However, domestic wells, abandoned wells, and other wells are sometimes used to save on costs. The selection of the location of a single observation well is critical. As a general rule, the observation well will be closer for an unconfined aquifer than for a confined aquifer. Drawdown data collected from observation wells that are too close to the pumping well(s) may be distorted by well loss effects; however, locating observation wells too far away may be outside the drawdown cone, and may cause boundary conditions to go unnoticed. Ideally, observation wells should fully penetrate the aquifer so that they measure the average head in the formation at that location. In some instances, additional observation wells may be required to observe drawdown impacts on wetlands or other natural features.

2.3.2. Pump Test Analysis

An analysis/interpretation of the constant rate test and/or step drawdown test shall be presented in the report. The degree of detail presented should be commensurate with the scale and scope of the project. This analysis may include, but is not limited to: graphical analysis of the data; calculations of aquifer characteristics, such as hydraulic conductivity, transmissivity, and storativity or specific yield where observation wells are used; identification of boundary conditions; an assessment of the potential drawdown at various times and selected distances from the pumping well(s); predicted drawdown in the potentially affected neighbouring wells (and surrounding vegetation and water bodies) compared to the available head and to the pump intakes.

The rationale for selecting a specific analytical method (including a discussion of its assumptions and limitations) should be clearly stated. Recognized methods for analyzing

pumping test data include, but are not limited to, the following: Cooper-Jacob (1946) Straight Line Approximation (confined, unsteady state); Theis (1935) Curve Matching Method (confined, unsteady state, pumping or recovery); Neuman (1975) Curve Fitting Method (unconfined, unsteady state, delayed response); Hantush-Jacob (1955) Method (leaky, unsteady state, no storage in aquitards); Hantush (1960) Method (leaky, unsteady state, with storage in aquitards); Thiem (1906) Method (confined, steady state); and Neuman and Witherspoon (1972) Method (leaky aquifers).

The report should include an assessment of the weather conditions before, during and after the pumping test (i.e. precipitation, barometric pressure changes, etc.) and how the weather may have impacted the test data. A brief description of the weather conditions in effect during the pump test must be included in the report.

2.3.3. Water Quality Analysis

Not all projects will require a detailed knowledge of water chemistry but the pump test affords a good opportunity to provide a benchmark against which future water quality may be compared. However, in the eventuality of a complaint, the Water Use Licensing Section may be concerned with changes in water quality as a result of the diversion (e.g. increased metal mobility, anaerobic/aerobic changes, salinity increases, turbidity, etc.).

Changes could be the result of inducing a different quality into the aquifer / zone because of pumping or changing physical characteristics of the water table which may in turn alter the chemistry. For example, the problem of introducing metals to groundwater occurs when the water table rises and zones become less oxidized; thereby causing Fe/Mn solids to dissolve and be released into the water. Proxy indicators for redox changes would include Fe, Mn, and SO₄.

Depending on the intended use of groundwater additional parameter analyses may also be requested by the proponent or other regulatory bodies. For example, irrigators may be requested to determine the sodium absorption ratio, which can be calculated from major elements (Na, Ca, and Mg), or municipal operators and food processors may be requested to obtain trace elements (F, Ba, B, As, etc.). It should be noted that, at all times, professional judgement should be exercised by the consultant.

All water quality analysis must be conducted at an accredited laboratory. In addition to water quality samples and field measurements, historical water quality data, when available, should also be evaluated to identify water quality trends. The report should provide a detailed assessment of the potential anthropogenic changes. The report should also include an interpretation of water quality analysis, and an assessment of whether or not the water quality is adequate for the intended use.

Where?	Why?	When?	What?	How?
Highly Confined Aquifers	To determine whether aquifer water is fossil or part of a more active flow system	Early stages of development	<p>General Chemistry (temp, pH, major cations /anions)</p> <p>Stable Isotopes ($\delta^{18}\text{O}$, D)</p> <p>Metals (Ca, Mg, Na, K, Cl, SO_4, & HCO_3^-)</p> <p>Minor Elements (Al, Fe, Mn)</p>	<p>Electrical conductivity readings should be taken throughout the pumping test regularly (e.g. hourly). Water samples should be taken 1 hour into the test, mid test and at the end of the test. If electrical conductivity does not vary by more than 10%, then only the final sample requires analysis. If electrical conductivity varies by more than 10%, then only the first and final samples require analysis. Only for extreme fluctuations in electrical conductivity would all three samples require analysis.</p> <p>(Note: Metals would require filtering at the well head to obtain the dissolved fraction)</p>
Ground-water / Surface Water Interactions	To determine in general terms (e.g. 0%, 25%, 50%, 75%, and 100%) whether water should be allocated from groundwater or surface water budget	Early stages of development and at a frequency to be designated by Water Use Licensing Section for at least one year	<p>General Chemistry (temp, pH, major cations / anions)</p> <p>Stable Isotopes ($\delta^{18}\text{O}$, D)</p> <p>Turbidity</p> <p>Metals (Ca, Mg, Na, K, Cl, SO_4, & HCO_3^-)</p> <p>Minor Elements (Al, Fe, Mn)</p>	<p>Electrical conductivity readings should be taken throughout the pumping test regularly (e.g. hourly). Water samples should be taken 1 hour into the test, mid test and at the end of the test. If electrical conductivity does not vary by more than 10%, then only the final sample requires analysis. If electrical conductivity varies by more than 10%, then the first and final samples require analysis. Only for extreme fluctuations in electrical conductivity would all three samples require analysis.</p> <p>(Note: General Chemistry, Temperature and Isotopes to be taken for both groundwater and the nearby surface water body)</p>

Table 2: Determining Water Quality Parameters to be Investigated

2.4. Evaluation of Potential Effects

The evaluation of potential effects typically includes the following information: permissible withdrawal limits, well interference effects, and water quality effects. However, site-specific conditions such as the buried valley aquifers, saline-fresh water boundaries, groundwater-surface water interaction or any other condition which has the potential to impact on existing groundwater users or the environment may need to be evaluated.

There are many methods available to evaluate potential effects, including field measurements and groundwater modeling. Numerical modeling is not normally required for the issuance of a water rights licence. However, if the geological and hydrogeological conditions are conducive to modelling and/or the project may have an unknown impact on neighbouring wells and/or the environment, a numerical model may be warranted. If the proponent uses a numerical groundwater model and version, details must be included in the report. Details should include but are not limited to the following: software name and version, and provide assumptions and limitations of the model, how the model was built and calibrated, and what are the predicted results and uncertainties.

2.4.1. Permissible Withdrawal Limits

The permissible withdrawal limits of an aquifer may be defined as the total groundwater withdrawals that can be maintained indefinitely without causing unacceptable environmental, economic, or social consequence.

Where permissible withdrawal limits of aquifers have been established, the Department of Conservation and Water Stewardship has allocated as little as 15% and as much as 100% of the assumed naturally occurring recharge to an aquifer or aquifer sub-basin to licensable uses, depending upon the local socio-economic environment. The most common apportionment of the permissible withdrawal limits of an unconfined aquifer is 50% to licensable uses and 50% to domestic and ecosystem uses.

Setting permissible withdrawals of an aquifer is the sole jurisdiction of the Department of Conservation and Water Stewardship to initiate. However, in some cases, it may be appropriate for a water balance to be prepared by the consultant to help assess whether the aquifer can sustain the proposed development.

2.4.2. Third Party Interference

The location of nearby groundwater users must be identified and the potential well interference effects on these wells must be assessed and described in the report. Groundwater users include both licensed water allocations and domestic water wells. Where nearby licensed users are present, identifying cumulative impacts, if any, must be discussed. The scope and extent of the third party well survey is outline in Section 2.7.1.

Additional quantitative predictions may be made with analytical and/or numerical groundwater models (e.g. Theis Equation, Modflow, etc.). Well interference predictions

should be made using conservative assumptions and input data. The predictions should include an evaluation of well interference effects with no recharge.

Based on the above evaluation, if significant well interference effects are expected then a contingency plan acceptable to the Water Use Licensing Section may be required. It will be up to the consulting hydrogeologist to explain why any impact is not “significant”.

2.4.3. Water Quality

The viability of the project (e.g. municipal water supply projects) may require the assessment of the potential effects of any nearby sources of contamination, including: naturally occurring poor groundwater quality such as induced recharge from adjacent formations and non-naturally occurring poor groundwater quality such as the Rockwood Contamination Plume. The assessment should discuss the location of any sources of poor water quality with respect to the recharge area for the well field and whether or not there will be a hydraulic gradient towards the well field.

2.4.4. Groundwater-Surface Water Interaction

An evaluation of the potential for groundwater / surface water interaction should be included if the well is completed in an unconfined or semi-confined aquifer and is under the influence of a nearby surface water body. Groundwater / surface water depletion effects may be considered significant if baseflow is predicted to be reduced by more than a critical percent or if the flows in the stream are predicted to drop below the established in-stream flow level (if a specified instream flow level is available).

For public and semi-public water systems, groundwater under the direct influence of surface water (GUDI) analysis may be required by the Office of Drinking Water. A link to the Drinking Water Safety Regulation is provided below:

<http://www.gov.mb.ca/waterstewardship/odw/reg-info/acts-regs/040-d101.07.pdf>

2.4.5. Other Considerations

Special consideration should be given to the following circumstances: buried valley aquifers and saline-fresh water boundaries. With regard to buried valley aquifers, the assessment should discuss the recharge potential and boundary effects. Examples of buried valley aquifers in the province include, but are not limited to, the following: Assiniboine; Brandon; Hatfield; Pierson; and, Spiritwood. With regard to saline-fresh water boundaries, the assessment should discuss the potential for movement of brackish and/or saline waters into historic fresh water areas. Saline-fresh water boundaries in the province include, but are not limited to, the following: Red River Formation – Winnipeg Formation and the Winkler Aquifer.

2.5. Meeting Other Regulatory and Permitting Processes

Many water rights licensing projects are undertaken for municipal water supply projects. The consultant is reminded that other regulatory agencies such as The Office of Drinking Water and the Environmental Assessment and Approvals Branch may have specific requirements for water chemistry testing that go beyond what may be required to obtain a water rights licence.

In addition, a revised *Groundwater and Water Wells Act* received Royal Assent on June 14, 2012. This Act contains a number of provisions pertaining to the proper completion of both supply and monitoring wells.

Finally, both the proponent and consultant must remain aware of a range of incidental requirements when planning a water supply project including acquiring legal access to both private and public lands for the establishment of works. Public lands can include municipal and provincial road allowances and undeveloped Crown Lands.

2.6. Monitoring and Contingency Plans

2.6.1. Monitoring Plan

At a minimum, all licensees will be required to maintain water use records and submit said records annually. Owners of air cooling and/or heating systems will also be required to keep supply and return temperatures and submit said records annually.

Monitoring of other parameters, such as water levels, water temperatures, and water chemistry, may also be required depending on usage and site specific conditions and potential effects. Often third party concerns may be addressed by a single long-term monitoring well equipped with a pressure transducer maintained by the proponent and/or province; however, occasionally the proponent is required hire a qualified hydrogeologist to oversee a monitoring program and compile operating results into a report and submit said report annually. In some instances such reports have been shared with third parties such as rural municipality councils and local aquifer management boards and conservation districts. This provides the necessary transparency and accountability that some situations demand.

2.6.2. Contingency Plan

Applicants may be required to prepare a groundwater interference response plan for mitigation of drawdown effects. The plan should specify the circumstance(s) that will trigger the implementation of the plan. It is desirable to have an appeals mechanism in place.

To date such plans have been prepared by several municipalities and for the Winnipeg Floodway expansion project.

2.6.3. Other Requirements

The Water Use Licensing Section may require additional information, depending on the nature of the withdrawal. Situations that may trigger requests for additional information may include, but are not limited to: large scale withdrawals (e.g. exceeding *The Manitoba Environment Act* Phase II threshold trigger) and withdrawals located in a sensitive setting (i.e. aquifers approaching their permissible withdrawal limit and/or showing long term water level decline and/or in close proximity to valued wetlands).

2.7. Additional Information

2.7.1. Survey of Neighbouring Wells

The purpose of the well survey is to obtain baseline data, should any well interference complaints arise in the future. The scope and extent of the survey will vary with the project.

The survey would include, as a minimum, the closest off-site wells to the project well(s) but may extend to include all wells within a specified distance (i.e. 800 m is typical in an urban setting and 1600 m is common in a rural setting but longer distances may be required). An example of where the specified distance might be increased or decreased depending on circumstances is a neighbouring rural subdivision utilizing water wells as water sources for individual homes.

Generally a desktop survey is required that includes, but is not limited to, the following information: identification of nearby wells (including active, abandoned, and decommissioned wells), details of each well (age, status, use, depth, static water level, current owner, yield, PID number, and geographic coordinators (UTM - NAD83).

Occasionally a field survey is requested that includes, but is not limited to, the following information: specific capacity tests, water quality tests, and details of pumping systems (i.e. submersible pump, shallow or deep jet, pressure tank, water treatment equipment, etc.).

It is acknowledged that some of the information listed maybe be subject to *The Freedom of Information and Protection of Privacy Act* (“*FIPPA*”).

2.7.2. Supporting Data and Figures

A site location and land ownership map must be submitted. Aerial photographs, topographic maps, and cross sections are also encouraged.

The applicant must submit all raw pumping test data, graphs, and a summary of the pumping test data and analysis in electronic format.

The report must include the relevant water quality analysis laboratory certificates in electronic format.

For a public or semi-public water supply system, a map showing potential contamination sources in relationship to setback distances may prove useful to third party readers (e.g. The Office of Drinking Water).

2.7.3. Water Well Complaints

All complaints related to water well interference should be reported to 204-945-3983 in Winnipeg or 204-834-6011 in Carberry.

3. ADDITIONAL REFERENCES

ALBERTA ENVIRONMENT. 2011. Guide to Groundwater Authorization.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. 2005. Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques.

NOVA SCOTIA ENVIRONMENT. 2010. Guide to Groundwater Withdrawal Approvals.

ONTARIO MINISTRY OF ENVIRONMENT. 2008. Technical Guidance Document for Hydrogeological Studies in Support of Category 3 Applications for Permit to Take Water.

UNITED KINGDOM ENVIRONMENT AGENCY. 2007. Using Science to Create a Better Place: Hydrogeological impact appraisal for groundwater abstractions.

4. APPENDIX A: SUBMISSION CHECKLIST

Hydrogeological Study - General Requirements			
Task	Sub-Task	Included in Report (= Yes)	Report Page No.
Site Description	Site Description	<input type="checkbox"/>	Page No. __
	Well Field Description	<input type="checkbox"/>	Page No. __
	Description of Intended Water Use	<input type="checkbox"/>	Page No. __
	Groundwater Withdrawal Details	<input type="checkbox"/>	Page No. __
	Description of Existing and Previous Water Withdrawal Approvals	<input type="checkbox"/>	Page No. __
Description of Hydrogeology	Regional and Local Hydrogeology and Surface Water Features	<input type="checkbox"/>	Page No. __
Pump Test Information	Pumping Test Analysis	<input type="checkbox"/>	Page No. __
	Water Quality Analysis (if required)	<input type="checkbox"/>	Page No. __
Evaluation of Potential Impacts	Permissible Withdrawal	<input type="checkbox"/>	Page No. __
	Well Interference Effects	<input type="checkbox"/>	Page No. __
	Water Quality Effects	<input type="checkbox"/>	Page No. __
	Groundwater-Surface Water Interaction	<input type="checkbox"/>	Page No. __
	Other Considerations	<input type="checkbox"/>	Page No. __
Supporting Figures and Data	Site Location Map and Site Plan	<input type="checkbox"/>	Page No. __
	Well Logs	<input type="checkbox"/>	Page No. __
	Pumping Test Data and Graphs	<input type="checkbox"/>	Page No. __
	Laboratory Reports	<input type="checkbox"/>	Page No. __
Notes on General Requirements			
Withdrawal Approvals and Hydrogeological Studies are required for groundwater withdrawals greater than 25,000 Litres per day, which equates to 10 Cubic Decametres per year, (e.g. livestock and irrigation projects) or less (e.g. municipal and industrial projects).			
Reports must be submitted in both hard copy and electronic formats including data sets.			
A constant rate pump test/analysis is required for each pumping well included in the application.			
Production well(s) must be pump tested at a rate greater than or equal to the requested withdrawal rate on the application form.			
Well interference effects should be evaluated for wells within 800 m or less in a urban setting and 1600 m or less in a rural setting from the well field.			
Groundwater-surface water interaction effects may need to be evaluated if the well field is within 60 m of a surface water body.			
Recharge potential and boundary conditions may need to be evaluated if the well field is completed in a buried valley aquifer.			
Potential for movement of brackish and/or saline waters into historic fresh water areas should be discussed if well field is completed adjacent a saline-fresh water boundary.			
Other information may be required for large groundwater supply projects. See main guide text.			

Table 3: Submission Checklist for Hydrogeological Studies

5. APPENDIX B: PUMP TEST DESIGN

Number of Pumping Hours Per Day	Number of Pumping Days Per Year	Anticipated Maximum Yearly Water Requirement	Length of Pumping & Recovery Test at Anticipated Maximum Pumping Rate (90% recovery is also acceptable)		Number of Observation Sites
			Confined	Unconfined	
Applicant to enter	Applicant to enter	Up to 10 dam ³	2 + 2 hours (or longer)	2 + 2 hours (or longer)	0
Applicant to enter	Applicant to enter	10 dam ³ to 100 dam ³	8 + 8 hours (or longer)	8 + 8 hours (or longer)	0-1
Applicant to enter	Applicant to enter	100 dam ³ to 200 dam ³	8 + 8 hours (or longer)	24 + 24 hours (or longer)	1-2
Applicant to enter	Applicant to enter	Greater than 200 dam ³	24 + 24 hours (or longer)	72 + 72 hours (or longer)	≥ 2

Table 4: Design of Pump Test for the Anticipate Annual Diversion

NOTE: Despite the fact that a longer pump test is not necessarily required for permitting purposes, the client may benefit from a longer pump test to minimize unforeseen problems / conflicts. In some other cases, a longer pump test may not be enough time to prevent negative results / effects in the future. The length of pump test will remain a judgement call by the consulting hydrogeologist based on geologic evaluation of site and aquifer. The consulting hydrogeologist must use his or her discretion during the test to observe responses and to evaluate whether the pump test should be extended. The consulting hydrogeologist should also consider in advance, or while onsite, as to the long term value to the proponent of maintaining one or more observation wells for risk management purposes.