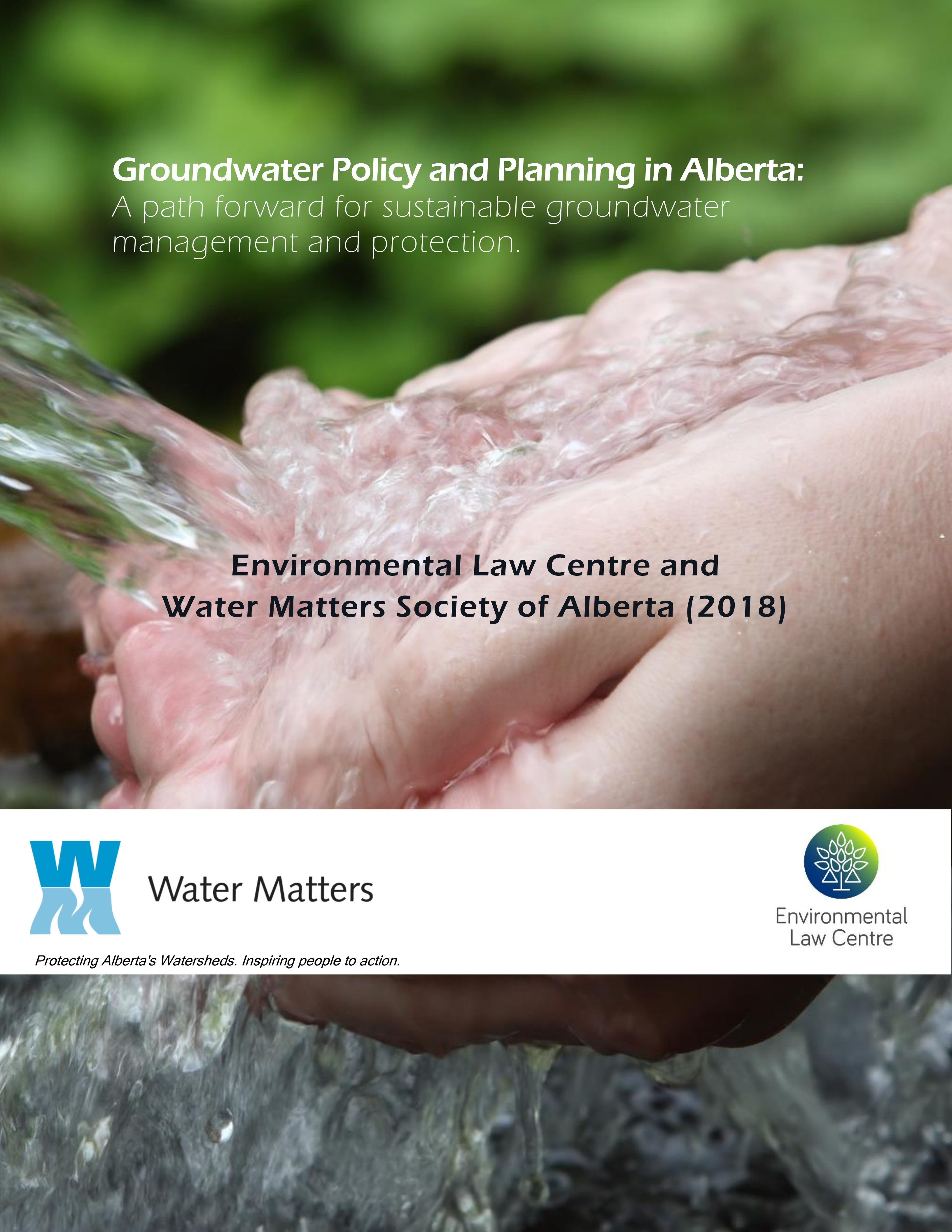

Groundwater Policy and Planning in Alberta:

A path forward for sustainable groundwater management and protection.

Environmental Law Centre and
Water Matters Society of Alberta (2018)

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Executive Summary

Groundwater management in Alberta is governed by a wide variety of regulation and policy. Long term sustainability and protection of groundwater supplies requires a more unified groundwater management system focused on groundwater assessment, planning and compliance responsiveness.

A proposed *Groundwater Management Framework for Alberta* should integrate core management principles to guide all decisions related to groundwater use and protection.

These management principles include:

- Protection of the quality and quantity of groundwater resources;
- Clear standards and processes;
- Environmentally sustainable water management;
- Continuous improvement; and
- Application of precaution in administration of groundwater authorizations and policy.

These principles are focused on addressing knowledge gaps and modelling uncertainty (including climate variability, yield, and recharge), risks of significant and irreparable harm (resulting from compromised quality or supply), and risks of degradation to natural systems.

These principles should guide the development and implementation of a groundwater policy framework which is based on scalable, iterative groundwater assessments of yield and vulnerability, and integrated planning for the protection of groundwater resources, other groundwater users, and groundwater dependent ecosystems (GDE). Assessment and planning for sustainable groundwater management must be further augmented by assurances of regulatory responsiveness where quality and quantity impacts arise.

A) Groundwater Assessment

Groundwater assessment must be guided by identifying risks at scales appropriate to relevant groundwater and environmental objectives. Relevant areas of assessment include watershed, aquifer delineation, recharge mapping, source risks mapping, vulnerability mapping (pathway), and receptor mapping (anthropogenic and ecological). These nested mapping assessments should feed directly into planning documents, policy and decision making.

i) Groundwater risk assessments and vulnerability mapping

There is a need to reinvigorate and update groundwater vulnerability assessments in the province. These assessments (and the efficacy of these assessments) are crucial to identifying areas of risk to water quality. Groundwater risk assessments must be scalable to delineate extent of vulnerability on the surface as well as subsurface pathways and aquifers. The assessments should delineate groundwater protection or safety zones based on identified surface vulnerability, and risks to subsurface pathways and aquifers.

ii) Groundwater quantity and recharge mapping

Groundwater recharge assessment and mapping are needed to guide planning and management decisions. Generally, Alberta has not focused on identifying and promoting holistic and integrated management of groundwater-surface water interactions. Assessment of impacts on recharge and source contributions to aquifer sustainability would inform decision making.

iii) Groundwater yield assessments

Decisions around new and ongoing groundwater diversions must be informed by appropriate assessments of water yield to ensure long term supply and effective protection for surrounding hydrologically reliant ecosystems. Yield assessments should be iterative and evolve with knowledge of specific aquifer characteristics. Near-term changes to yield methodologies and modelling are required.

In addition, climatic variability needs to be incorporated into modelling at the macro (basin) level, as well as at more specific (micro) aquifer levels, as assessments of risks direct.

B) Groundwater Planning

Groundwater planning should be integrated across relevant jurisdictions and groundwater assessments inform planning decisions across government agencies and levels of government.

i) Yield planning and decision-making

Planning documents and decision making policies need to directly address groundwater yield concerns. A protective and precautionary approach requires that groundwater yield assessments inform day-to-day decisions regarding groundwater withdrawals (made by Alberta Environment and Parks (AEP) and the Alberta Energy Regulator (AER)).

Yield planning will rely on both groundwater and land-based information systems. Robust groundwater assessments need to be integrated into water management plans under Alberta's *Water Act* to guide discretionary decisions that may result in impacts on groundwater supply, quality and ecosystems.

Yield planning should also consider effects on yield and supply of land use and changes in land use. Recharge zone maps and hydrological considerations regarding land use and water diversion should be integrated. Regional planning may provide an opportunity to integrate land and water yield considerations and can mandate project-based and sector-based assessments.

ii) Planning for groundwater vulnerability: quantity and quality

Regulatory and municipal plans need to incorporate guidance and/or direction regarding assessed groundwater vulnerability. This guidance and direction may be incorporated into regional or sub-regional plans under the *Alberta Land Stewardship Act*. By incorporating groundwater vulnerability assessments and aquifer recharge information into land use plans a direct linkage will be made by decision-makers between land use and groundwater impacts.

iii) Jurisdictional integration of yield and quality planning

Assessments of groundwater vulnerability must be integrated into planning at relevant scales. This will likely involve all jurisdictions: federal, provincial and municipal. Pathways of effects identified through assessment processes should guide planning decisions and future decisions around groundwater diversions and use.

While the majority of groundwater-based decisions lie with the province it is important to integrate information into federal, indigenous and municipal decision making as well. For example, relevant information for potential impacts on fisheries and navigable waters must be framed within federal powers. Similarly, the impacts of land cover change and land development on groundwater will be highly relevant to municipal planning.

iv) Regional planning capacity and commitments

Regional planning can function as a mechanism for integrating management of both land and water resources. Implementation of the integrated planning approach proposed in this report will require clear policy direction as well as commitment of sufficient resources.

C) Regulatory Responsiveness to Groundwater Impacts

The concept of "regulatory responsiveness" in relation to groundwater resources is focused on ensuring a robust system of ongoing monitoring, assessment and where needed, remedial and/or compliance action when groundwater impacts occur. Groundwater regulatory responsiveness must be able to address threats to groundwater quantity and quality, whether that is related to wellhead vulnerability, land use, unsustainable yield, or subsurface vulnerabilities.

Groundwater protection encompasses a broad range of quality and quantity risks linked with various legislative mandates and legal and geographic jurisdictional constraints. There is a need to ensure compliance responsiveness exists across sectors and is timely in responding to monitoring and assessment information.

D) A Path Forward

A groundwater policy framework should ensure groundwater sustainability and management accountability. The Environmental Law Centre and Water Matters recommend adopting the following approach to groundwater policy to move towards management that protects and sustains groundwater.

Ensure water quantity testing and modelling is sufficient to address long term groundwater sustainability, climate uncertainty, and "ecohydrology". Recommended measures include:

i) Abandon the Q_{20} test in favour of more accurate modelling and yield testing.

ii) Adopt regulatory tools to assess groundwater extraction impacts on ecohydrology or groundwater dependent ecosystems (GDEs).

iii) Ensure any renewals of groundwater diversion approvals/licenses are accompanied by appropriate modelling (consistent with the above two measures).

iv) Formalize assessment and articulate uncertainty in relation to groundwater models and assessments (using relevant statistical methodologies).

v) Review permanent water licences to assess licence terms and adjust yield calculations as needed.

vi) Where licence conditions appear to limit the feasibility of reassessment of yields, ecohydrology impacts and diversion rates, seek voluntary compliance with revised diversion rates. Create a public registry where more appropriate diversion rates can be accessed.

vii) Integrate yield and GDE data into planning and regulatory decisions across jurisdictions by way of water management plans and regional planning.

viii) Introduce a precautionary factor to authorized diversions where evidence dictates.

ix) Identify high priority water recharge and yield areas based on groundwater sustainability criteria.

Ensure groundwater quality is maintained or improved.

Recommended measures include:

i) Ensure risk and vulnerability mapping is scalable to inform decisions.

ii) Formalize groundwater risk assessment and mapping in a regulatory approach.

iii) Formalize groundwater risk management planning and responses through regulation (e.g., regional planning). This includes clear integration of groundwater risk assessments into authorization decisions by the province (under the *Water Act*, *Environmental Protection and Enhancement Act*, *Agricultural Operations Practices Act* and other legislation relevant to the Alberta Energy Regulator) and by municipal governments.

iv) Include both surface vulnerability and subsurface pathways in risk assessments.

v) Create an integrated risk database and registry that are geographically based, with data collected from various risk analyses undertaken by government and activity proponents.

Ensure timely compliance.

Recommended measures include:

i) Set out regulatory compliance and enforcement policy for groundwater impairment.

ii) Set out authority to prescribe management responses to existing and new activities, regardless of risk level (i.e. ensure that source water protection planning is enforceable).

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Introduction

Groundwater management is a complicated business. Groundwater policy is similarly burdened with complexities as policy must deal with significant levels of uncertainty, a need for integrated land and water management and a need for significant scientific capacity. This report is focused on moving Alberta past its current policy framing of groundwater management and regulation.

The report details some of the current pressures on the groundwater resource, sets out a summary of current groundwater regulation in Alberta and delineates a path forward for framing groundwater policy in the province.

A general introduction to groundwater can be found in Appendix A to provide context to the groundwater discussion. Groundwater management and protection is complex with a variety of challenges.

Part I: Current groundwater management challenges in Alberta

Groundwater management and protection is a complicated area for environmental governance as it deals with land and water use and encompasses management of activities above and below the earth's surface. This complexity is a result of water's ubiquitous and difficult to control nature.

Some key governance challenges in groundwater management and protection include:

- Information gathering systems and capacity sufficient to generate appropriate levels of groundwater knowledge for informed decisions;
- Regulatory structures able to assess, plan and regulate for groundwater management outcomes across sectors at various geographic scales;
- Government capacity to ensure effective oversight, review and compliance of groundwater regulation;
- Technical capacity within industry and government sufficient to meet evolving assessment and planning objectives; and
- Clarity in jurisdiction over groundwater management in relation to land management.

Technical and capacity challenges exist for several aspects of groundwater management including aquifer sustainability, land use impacts on groundwater recharge, impacts on ecosystems and biota reliant on groundwater, and climate variability. The broadly encompassing nature of an appropriate groundwater management policy and implementation of effective, integrated and protective regulation elicits political concerns and may have economic implications.

A catalogue of potential stressors on groundwater sources in many ways mimics the stressors on surface water. Many of the potential stressors relate to human health, human use, and risks to surrounding environments.

Groundwater quantity challenges

Having a reliable supply of water is essential to quality of life and economic activity. Where groundwater resources are overdrawn or uncertainty exists regarding long term supply, there is heightened risk of having water allocations reduced and conflicts among users. In addition, there are potential environmental impacts of groundwater extraction on aquatic and terrestrial ecosystems.

Managing to sustain groundwater supply is made especially difficult by the complexity of variables at play. Climatic conditions, anthropogenic impacts related to land use and extractive activities, and limited modelling and monitoring of recharge/discharge rates all contribute to a water quantity management conundrum.

Licenced groundwater allocations in Alberta reached 300,312,720 m^3 in 2010, representing a small portion of water diversions (~3%).[1] Unlicenced groundwater diversions for household use (and other unlicenced uses) add to this amount but an accurate volume of use is not readily quantifiable. Relative to surface water use groundwater diversions and use is small, however; specific geographic regions and some sectors may see higher demands for groundwater extraction.[2] An understanding of the impacts of these diversions remains highly uncertain.

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1 Alberta Environment and Parks, Groundwater Use, (Government of Alberta, 2011), online: Government of Alberta,
https://open.alberta.ca/publications/focus-on-groundwater-groundwater-use.
2 T.G. Lemay and S. Guha, *Compilation of Alberta groundwater information from existing maps and data sources* (ERCB/AGS 2009), http://ags.aer.ca/publications/OFR_2009_02.html. Also T.G. Lemay, *Assessment of Non-saline*

A central area for concern is the methodology used to accurately predict groundwater yields and collateral effects of withdrawals. For example, the Q_{20} approach used broadly to assess sustained yield in Alberta in the past has various assumptions about aquifer uniformity and fails to adequately adjust to variable recharge on longer time horizons.[3]

Maathus and van der Kamp cite several examples of Q_{20} regional inadequacies noting:

> *These case histories illustrate very clearly that for heterogeneous aquifers, such as are common within the Paskapoo formation, Q_{20} estimates that are based on short-term pumping tests cannot be relied upon to reflect the long-term response of the well-aquifer system to pumping.* [4]

Aquifer heterogeneity and leakage has also been observed to undermine the accuracy of this approach.[5] The Alberta Geological Survey has similarly recognized the shortcomings of the current methodology and recommended alternate approaches.[6]

Existing groundwater maps (such as the *Provincial Groundwater Atlas*) must be evaluated in light of significant uncertainty. This uncertainty includes the impacts of hydrology on groundwater dependent ecosystems (GDEs) or biota and the emerging field of "ecohydrology".[7]

Water Use in Alberta's Upstream Oil and Gas Sector between 2004 and 2013: Implications on Forecasted Water Use (AER and AGS, 2015), http://ags.aer.ca/document/Presentations/CON_Lemay_CNC2015.pdf . Increases in unconventional plays are also resulting in higher diversion rates in some areas, primarily from surface water.
3 H. Maathuis and G. van der Kamp, The Q_{20} concept: sustainable well yield and sustainable aquifer yield (Saskatchewan Research Council, 2006), https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=292074. This report recommends discontinuation of the Farvolden Q_{20} method and supports a R20 method.
4 *Ibid*. at p. 32.
5 E.A. Munroe, E*ffect of Aquifer Heterogeneity on Estimation of Permissible Long-Term Groundwater Extraction Rates* (M.Sc. Thesis, Geology and Geophysics, University of Calgary, 2015).
6 D. Palombi, L. Atkinson, A. Singh, "Evaluating a Nested-Scale 3D Modelling Approach to Enhanced Groundwater Policy Assurance in Alberta" (presentation, AGS, undated), http://ags.aer.ca/document/Presentations/CON_Palombi_NestedScale.pdf. Also D. Palombi, "Integrated Numerical Modelling into Groundwater Policy Assurance Process", (presentation, Watertech 2014, AGS, April 10, 2014), http://ags.aer.ca/document/Presentations/CON_Groundwater_Palombi.pdf. Also Lemay and Guha, *supra* note 3.
7 R.J. Hunt, M. Hayashi and O. Batellan, "Ecohydrology and its relation to integrated groundwater management" in A.J. Jakeman *et al*. (eds.), *Integrated Groundwater Management: Concepts, Approaches and Challenges* (Springer, 2016), http://wcm.ucalgary.ca/hayashi/files/hayashi/hunt_etal_2016.pdf. Also see D. Eamus, Baihu FU,

Lemay and Guha of the Alberta Geological Survey (AGS) note:

> *The examination of estimates of groundwater use, compared to the expected yield of geological materials, shows that there could be areas where groundwater use exceeds the capacity of the units, which will have an impact on other elements of the hydrological cycle, such as lakes, rivers or wetlands.*[8]

Similarly Parks *et al.* of the AGS in their groundwater resource appraisal of the Cold Lake - Beaver Drainage Basin, observe:

> *The key learning of this study is that evidence shows that groundwater in drift aquifers is hydraulically connected to surface water and that groundwater development in drift aquifers could interact with surface water within five years of initiation of pumping. This means that conjunctive management approaches to surface and groundwater management should be considered. The locations and degree of surface-groundwater interactions for each development are not well known and require further study.*[9]

Groundwater quality challenges

Compromised groundwater quality may result in long term or irreparable harm to the resource. Groundwater protection from contamination is essential to protect the groundwater resource for future sustainable use. Water quality concerns include:

- Natural presence of potentially harmful substances such as arsenic, fluoride, and lead.
- Introduction of natural substances from surface water including bacterial coliforms and nutrients (which may also result from human activity).
- Landscape based activities and pollutants that risk contamination of groundwater aquifers with:
    - Pesticides[10]

A. E. Springer and L.E. Stevens "Groundwater Dependent Ecosystems: Classification, identification techniques and threats" in A.J. Jakeman *et al.*, *supra*.

8 Lemay and Guha, *supra* note 3.

9 K. Parks, K., L.D. Andriashek, L.D., K. Michael, K.,T. Lemay, T.,S. Stewart, S.,G. Jean, G.,and E. Kempin,, E. (2005): *Regional Groundwater Resource Appraisal*, *Cold Lake-Beaver River Drainage Basin*, *Alberta*, ; Alberta Energy and Utilities Board, (EUB/AGS Special Report 74, 2005). http://ags.aer.ca/document/SPE/SPE_074.PDF.

10 C. Sheedy, *Investigation of the Occurrence of Agricultural Pesticides in Groundwater of Alberta*, (Agriculture and Agri-Food Canada, April 30, 2016).

- Coliforms and viruses[11]
- Nutrients[12]
- Chemical contaminants[13].

- Physical interference (through seismic activity or inter-well communication) with aquifers which may compromise water quality (including methane).

A long list of land uses, from agricultural to industrial to residential, may pose risks to groundwater. Risks arise from storage, manufacturing, intentional and accidental releases of chemicals (including pesticides, pharmaceuticals and organic compounds), biologicals and nutrients.[14] The sources of potential contamination have been catalogued previously (see Table 1 below).[15]

Each land use and sector will generate various risks. For example, oil and gas activities may have related seismicity impacts which result in aquifer changes.[16] The pathways by which contamination reaches groundwater will vary in relation to source and must be assessed accordingly.

11B.M. Olson, J.J. Miller, and S.J. Rodvang, *Soil and groundwater quality monitoring under a research feedlot in southern Alberta*. (AAFRD and AAFC, Lethbridge, 2002), http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/irr15472/$FILE/soil_groundwater_quality_monitoring_under_research_feedlot.pdf.
12 M. Sebilo, B. Mayer, B. Nicolardot, G. Pinay and A. Mariotti, "Long-term fate of nitrate fertilizer in agricultural soils" Proceedings of the National Academy of Sciences 110 (45) (2013). http://www.pnas.org/content/110/45/18185.full.
13 M.M. Savard, J.M.E. Ahad, P. Gammon, A.I. Calderhead, A. Rivera, R. Martel, M. Klebek, J.V. Headley, R. Lefebvre, B. Welsh, A. Smirnoff, H. Pakdel, N. Benoit, S. Liao, J. Jautzy, C. Gagnon, J. Vaive, I. Girard, and K. Peru, *A local test study distinguishes natural from anthropogenic groundwater contaminants near an Athabasca oil sands mining operation* (Geological Survey of Canada, 2012), https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=292074.
14 L. Ritter, K. Solomon, P. Sibley, K. Hall, P. Keen, G. Mattu and B. Linton "Sources Pathways, and Relative risks of contaminant in surface water and groundwater: A perspective prepared for the Walkerton Inquiry" in *Journal of Toxicology and Environmental Health*, Part A 65:1-142. (2002), http://www.hydrorelief.org/frackdata/references/RisksContamWater.pdf.
15 *Ibid*.
16 G.M. Atkinson, D.W. Eaton, H. Ghofrani, D. Walker, B. Cheadle, R. Schultz, R. Shcherbakov, K. Tiampo, J. Gu, R.M. Harrington, Y. Liu, M. van der Baan, and H. Kao, *Hydraulic Fracturing and Seismicity in the Western Canada Sedimentary Basin. Seismological Research Letters*, Volume 87(3), (May/June 2016), http://www.inducedseismicity.ca/wp-content/uploads/2015/01/CISC_SRL2015-final.pdf. See also U.S. Environmental Protection Agency, *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources* (External Review Draft), (EPA,2015), https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=244651. Seismic events may be induced by downhole injection of wastewater as well as by hydraulic fracturing.

Table 1: Sources of Groundwater Contaminants
(Ritter et al. 2002, adapted from Barcelona et al (1990).

Category 1: Sources designed to discharge substances

1 Sub-surface percolation from septic tanks/ cesspools
2 Injection wells
- Hazardous waste
- Nonhazardous waste (e.g., brine disposal)
- Nonwaste (e.g., solution mining)

3 Land application
- Wastewater (spray irrigation)
- Wastewater by-products (biosolids)
- Hazardous waste
- Nonhazardous waste

Category 2: Sources designed to store, treat, and/ or dispose of substances; discharge through unplanned release

1 Landfills
- Industrial hazardous waste
- Industrial nonhazardous waste
- Municipal sanitary

2 Open dumps, including illegal dumping
3 Residential disposal
4 Surface impoundments
- Hazardous waste
- Nonhazardous waste

5 Materials stockpiles (nonwaste)
6 Graveyards
7 Animal burial
8 Above-ground storage tanks
- Hazardous waste
- Nonhazardous waste
- Nonwaste

9 Underground storage tanks
- Hazardous waste
- Nonhazardous waste
- Nonwaste

10 Containers
- Hazardous waste
- Nonhazardous waste
- Nonwaste

11 Open burning and detonation sites
12 Radioactive disposal sites

Category 3: Sources designed to retain substances during transport or transmission

1 Pipelines
- Hazardous waste
- Nonhazardous waste
- Nonwaste

2 Materials transport and transfer operations
- Hazardous waste
- Nonhazardous waste
- Nonwaste

Category 4: Sources discharging substances as a result of other planned activities

1 Irrigation practices
2 Pesticide applications
3 Fertilizer applications
4 Animal feeding applications
5 De-icing salt applications
6 Urban run-off
7 Percolation of atmospheric pollutants
8 Mining and mine drainage
- Surface mine related
- Underground mine related

Category 5: Sources providing conduit or inducing discharge through altered flow patterns

1 Production wells
- Oil and gas wells
- Geothermal and heat recovery wells
- Water supply wells

2 Other wells
- Monitoring wells
- Exploration wells

3 Construction excavation

Category 6: Naturally occurring sources whose discharge is created and/or exacerbated by human activity

1 Groundwater–surface water interactions
2 Natural leaching
3 Salt water intrusion

Part II: Groundwater governance and regulation in Alberta

Government management of groundwater is found in a variety of laws, regulations and policies. This section of the report summarizes key aspects of groundwater governance and regulation in Alberta with additional details provided in Appendix A.

Groundwater use and protection is governed across various departments and jurisdictions. A brief review of regulations and programs governing groundwater quality and quantity in Alberta follows.

Quantity regulations

Water withdrawals and use in Alberta is governed by the *Water Act*.[17] Groundwater is defined under the *Water Act* as any water under the surface, whether in liquid or solid state.[18] Groundwater withdrawals may take place under licences, registrations or may be exempt from authorization requirements under the act or regulations.

Groundwater extraction activities that are exempt from licence or registration requirements include:

- Groundwater extraction for household use (up to 1250 m^3/yr) (although water well information is required under the *Water (Ministerial) Regulation*).[19]
- Manually pumped water wells.
- Diversions of saline groundwater (salinity threshold is 4000 ppm).[20]
- Diversions for the purpose of dewatering a sand and gravel site (in prescribed instances).
- Diversions for the purpose of firefighting.
- Temporary diversions for the purpose of hydrostatic testing of pipelines.
- Diversions for pesticide applications.

17 *Water Act*, R.S.A. 2000, c. W-3.
18 *Ibid*., s. 1(v).
19 *Water (Ministerial) Regulation*, A.R. 205/98, Part 7.
20 Diversions of saline groundwater (defined as 4000 mg/litre) are exempt from licence provisions of the Water Act, *supra* note 18, Schedule 3, s. 1(e).

a) Water wells and flow regulation

Water wells are also governed under the *Water Act* and *Water (Ministerial) Regulation*. These regulations set out the need to ensure wells are "designed and developed" to meet the owner's water requirements and to be within the production potential of the aquifer.[21] Flow control is required on wells and limits on flow are set at the lesser of the requirements of the owner or 100 cubic metres per week (except for licenced wells).[22]

Water well yield testing is required under the regulation with two hours of continuous pumping and two hours' recovery. Drawdown and recovery are reported to the government.[23]

b) Licenced and registered diversions

Water licences are required for most industrial purposes, for agricultural purposes which were not registered under the Act, or where volume limits are exceeded for household use (1,250 m^3/annum) or registration activities (6,250 m^3/annum).[24] The government retains broad discretion around authorizing groundwater diversion licences.[25] Conditions on these licences may include rates of diversion, requirements for monitoring yield of aquifers and limits on extraction (to prevent water mining).

The Director may consider the hydraulic, hydrological and hydrogeological effects of the activities before issuing an approval or licence.[26] The Director may also consider effects on other users, on the aquatic environment, on public safety, the suitability of land for irrigation and any other matters deemed relevant.

The Director may suspend water licences or approvals in an emergency (for public safety), or in the event of significant adverse effects on human health or public safety (that was not foreseeable at the time of the licence).[27] The Director may also suspend water licences where a significant

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21 *Water (Ministerial) Regulation*, *supra* note 23, s. 47(b).
22 *Ibid.*, ss. 55 -57.
23 *Ibid.*, s. 63 and s. 64.
24 *Water Act, supra* note 18, s. 1(x) and s. 19(1), respectively.
25 And preliminary certificates.
26 *Water Act, supra* note 18, s. 51.
27 *Ibid.*, s. 55(1).

adverse effect on the aquatic environment (which was not reasonably foreseeable) has or may occur.[28]

For the agricultural sector the *Water Act* allows those who owned land on January 1, 1999 and diverted groundwater to register the diversion (limited to a maximum of 6,250 m^3/year) and obtain the date of priority based on first use. Registrations can be cancelled or suspended where it is necessary for public safety. The ability to suspend or cancel registered diversions can also be used where water supplies are limited (i.e. more senior registrants may get access to water first) however this does not necessarily equate to protection of aquifer yields. Other relevant provisions enable the Director to establish water management areas for the purpose of groundwater management.[29]

Finally the Minister may create a variety of regulations determining sources of groundwater, measurement of water and various aspects of water wells.[30]

c) Groundwater authorization guidelines

The *Guide to Groundwater Authorization* applies to applications for licenced withdrawals. The *Guide* states the licensing application process aims to "(a) provide confidence in a sustainable supply of water for the applicant's needs; (b) protect the aquifer from overdevelopment; (c) protect the water supplies of household users, registration for traditional agricultural users, and prior licence holders; and (d) foster beneficial use of the resource, prevent speculation in water, and protect the environment".[31]

The *Guide* outlines the expected process for licence applications, including field surveys aimed at assessing current pressures on aquifers within 1.6 km of the project site.[32] Pumping test methods are also outlined and focus on pump rate, drawdown and recovery. An observation well(s) is required for well(s) pumping over 35m^3/day.[33]

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28 *Ibid*., s. 55(2) and compensation may be payable.
29 *Ibid*., s.164.
30 *Ibid*., s. 169.
31 Government of Alberta, *Alberta Environment Guide to Groundwater Authorization* (2011) at s. 1.2, https://open.alberta.ca/publications/5612701.
32 *Ibid*., s. 2.2.6.
33 *Ibid*., Appendix 4. Below 35m3/day and above 10m3/day an observation well "may" be used.

Collection of data to determine water quality is also set out in the *Guide*. The focus of the data is to assess the "long- and short-term impacts that could potentially result from a groundwater diversion". This assessment includes:[34]

- aquifer characterization (and delineation),
- interference with other users,
- proximity to surface water,
- well interference effects and 20-year yield modelling,
- predicted drawdown compared to available hydraulic head,
- public concerns,
- other potential issues requiring referral to other agencies,
- suitable models to assess groundwater flows and aquifer sustainability,
- localized sensitivities,
- evaluation of effects in terms of recharge needs in recharge dominated flow systems or for drought sensitive local water bodies, and
- changes in water quality as a result of the diversion.

The *Guide* prescribes required pumping tests and sets out data interpretation of aquifer tests.[35] The aquifer test assumptions and models used to define hydrogeological conditions are also described.[36]

Conclusion of quantity regulation

Alberta regulation relies on individual well yield testing to determine appropriate groundwater diversion rates. As noted earlier in this document Alberta's approach to assessing sustainable yield has been recognized as having shortcomings.[37] Beyond the modelling choice a broader understanding of climatic variability and eco-hydrology has yet to percolate into regulation and management of groundwater resource extraction.

34 *Ibid*., s. 2.3.1.
35 *Ibid*., s. 2.2.7 and s. 2.3.
36 *Ibid*., s. 2.3(c). See also sections related to groundwater authorizations where there is a connection to surface water.
37 Maathuis and van der Kamp, *supra* note 6.

Quality Regulations

The regulation of groundwater quality is overseen by various laws and several branches of government. While Alberta Environment and Parks maintains a central role in terms of ensuring *Water Act* and *Environmental Protection and Enhancement Act* provisions are met, a variety of other departments, tribunals, municipal governments and utilities play a role in groundwater management protection.

a) *Water Act*

The *Water Act* provides for a level of protection for groundwater through siting and technical requirements for water wells.

Siting criteria includes requirements that wells are:[38]

- accessible for maintenance, inspection and repair,
- kept in sanitary condition in areas in the immediate vicinity of the well,
- in locations where surface water does not collect in the vicinity of the well,
- at least 3.25 meters from buildings, and
- not located in pits.

Groundwater wells must not be drilled within setbacks provided in the *Water (Ministerial) Regulation* (see Table 2 below).[39]

Table 2: Water well setback distances (*Water (Ministerial) Regulation* Table 1)

Sources of Substance	Minimum Distance Required
Watertight septic tank or sewage holding tanks	10 metres
Sub-surface weeping tile effluent disposal field or an evaporation mound	15 metres
Sewage effluent discharge to the ground surface	50 metres

38 *Water (Ministerial) Regulation*, *supra* note 20, s. 44.
39 *Ibid*., s. 46.

Sources of Substance	Minimum Distance Required
Sewage lagoon	100 metres
Above ground storage tanks containing petroleum substances	50 metres

In addition water wells must be constructed in a manner to limit communication with surface water.[40] Casing and well completion requirements are also aimed at mitigating against risks of surface water communication or subsurface communications with other aquifers.[41]

The regulations also require government notification if drillers encounter saline groundwater.[42] The driller must seal it off to prevent mixing with non-saline groundwater.

The government retains discretion to take remedial measures. The Director may declare problem water wells which are having or may have adverse effects on environment, human health, property or public safety.

The *Water Act* also provides a level of protection of groundwater quantity and quality by virtue of requiring approvals for any activity involving the disturbance of groundwater that alters or may alter its flow or level, or affect the aquatic environment.[43]

Remedial measures may also be taken under the Act where the government finds there is an adverse effect. Water Management Orders may be issued where: [44]

- Works have not been properly maintained, repaired or improved, or the works fail;
- Any work, diversion or activity which does not require authorization under the Act is or has the potential of causing an adverse effect on the aquatic environment, human health, property or public safety;

40 *Ibid*., s. 47.
41 *Ibid*., s. 47.
42 *Ibid*., s. 43(1).
43 *Water Act, supra* note 18, s. 51.
44 *Ibid*., s. 97.

- Problem water wells that cause or may cause adverse effects;
- Drilling is causing or may cause an adverse effect on groundwater; and
- An activity, diversion of water or operation of works is causing a significant adverse effect on human health, property or public safety (with compensation if authorized under the Act).

Also under the *Water Act*, flood risk areas may be designated and subject to regulations setting out acceptable land uses.[45]

b) Environmental Protection and Enhancement Act

The *Environmental Protection and Enhancement Act* is focused on regulating polluting activities and requiring remediation once releases have occurred. In this way various general provisions are of relevance to groundwater protection and management. Some general provisions of interest include:

- Releases to the environment in excess of permitted amounts (s. 108);
- Unauthorized releases to the environment that cause or may cause a significant adverse effect (s. 109);
- Duties to report releases by those who release or cause or permit the release (s. 110);
- Duty to take remedial measures where substances cause an adverse effect (s. 112); and
- The ability to issue administrative orders, Environmental Protection Orders, for certain releases (s. 113).

In addition, the *Environmental Protection and Enhancement Act* is the primary regulatory instrument for managing potable water systems.

Activity specific regulations also apply which aim to minimize risks from regulated activities through conditions on approvals and codes of practice (for registration activities). Codes of practice which aim to minimize risks to groundwater include:

- *Code for Practice for Pits.*

45 *Ibid*., s. 96.

- *Code of Practice for Landfills.*
- *Code of Practice for Land Treatment of Soil Containing Hydrocarbons.*
- *Code of Practice for Wastewater Systems Consisting Solely of a Wastewater Collection System.*
- *Code of Practice for Wastewater Systems Using a Wastewater Lagoon.*

c) Remediation guidelines

Alberta Environment and Parks has also set out guidelines for remediation of soil and groundwater for releases into the environment and management and reclamation of specified land.[46] These guidelines focus on a risk management approach with either blanket requirements for remediation standards (Tier 1) or site specific remediation management (Tier 2).

For management of potable water, municipalities (or their utilities) may be required (as a condition of their approval) to undertake a "Drinking Water Safety Plan". These plans are focused on "four principals [sic]":[47]

- Collecting and evaluating the best information available about the water supply system.
- Analyzing and understanding potential risks.
- Correctly assessing risk mitigation – how to reduce risks to an acceptable level.
- Determining what resources and actions are necessary to ensure identified risks are reduced.

These plans may allow for water supply risk recognition and response however the approach is typically geared toward direct utility risks as upstream and source water management actions are typically beyond the scope of the authority and responsibility of the plan drafters.[48]

46 Alberta Environment and Parks, *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (February 2, 2016), https://open.alberta.ca/publications/1926-6243 and *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (February 2, 2016), https://open.alberta.ca/publications/1926-6251.
47 Alberta Environment and Parks, "Drinking Water Safety Plan", http://environment.alberta.ca/apps/regulateddwq/DWSP.aspx.
48 *Ibid*.

d) Regional planning and environmental management frameworks

Alberta has pursued regional planning processes which allow government to provide regional direction to those undertaking activities and making decisions relevant to groundwater protection and sustainability.[49] As of December 2017 two regional plans have been approved by the provincial cabinet.

The *Lower Athabasca Regional Plan* has a regulatory plan related to groundwater, which articulates objectives and strategies and sets out the intent to create a regulatory groundwater framework (and put in place an interim framework).[50] The intent of this framework is to deal with both quality and quantity concerns. Some triggers are set but no limits in terms of management outcomes.[51] The groundwater management framework has not been updated nor have there been formal reports regarding implementation of the framework since 2012. No groundwater management framework was put in place for the other approved plan, the *South Saskatchewan Regional Plan*.

Sector specific regulations

a) Oil and gas

Alberta moved environmental regulation for energy developments to the Alberta Energy Regulator (AER) starting in 2012. In addition to administering energy related statutes the AER administers the *Water Act*, the *Environmental Protection and Enhancement Act* and the *Public Lands Act*, among others, in relation to energy developments in the province. The AER therefore has a central role in ensuring groundwater protection is achieved. Groundwater policy for energy developments is still created by Alberta Environment and Parks.

Both quantity and quality concerns arise in the operations of the oil and gas sector. Exploration and production of energy resources, either by way of drilling or mining from surface, will often involve some interaction with potable aquifers. Also, groundwater may be diverted and used for production. The sector therefore has both operational and long term monitoring and

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49 Alberta's regional planning process was enabled through the *Alberta Land Stewardship Act* S.A. 2009 c. 26.8.
50 Government of Alberta, *Lower Athabasca Regional* Plan 2012-2022, https://open.alberta.ca/publications/9781460105382.
51 Government of Alberta, *Lower Athabasca Region Groundwater Management Framework* (2012), https://open.alberta.ca/publications/9781460105344.

management concerns related to groundwater. Front and centre in these concerns are well and casing integrity, waste management disposal (both at surface and downhole), inter-well communications, fracking and completion operations (which may result in seismic or inter-well communication concerns).

The full suite of regulations and directives relevant to the AER and the activities it regulates is beyond the scope of this report. Where harm to groundwater resources is likely to or has occurred, the AER has a variety of powers including to monitor, require reporting and order remediation. Beyond these general environmental management powers some of the AER groundwater specific regulations and directives for the oil and gas industry include:

- *Oil and Gas Conservation Rules* [52]– focused on regulating activities completed above the Base of Groundwater protection and requiring operators to maintain facilities and pipelines in manner that protects groundwater.[53]
- *Directive 009: Casing Cementing Minimum Requirements.*[54]
- *Directive 035: Baseline Water Well Testing Requirement for Coalbed Methane Wells Completed Above the Base of Groundwater Protection.*[55]
- *Directive 044: Requirements for Surveillance, Sampling, and Analysis of Water Production in Hydrocarbon Wells Completed above Base of Groundwater Protection.*[56]
- *Directive 083: Hydraulic Fracturing – Subsurface Integrity.*[57]

52 *Oil and Gas Conservation Rules*, A.R. 151/71.
53 *Ibid*., s. 8.150(4). "The licensee of a well or pipeline and the operator of a facility shall maintain the well, pipeline or facility in a clean condition and shall ensure that oilfield wastes do not create or constitute a safety hazard or nuisance or adversely affect air, soil, surface water or groundwater."
54 Alberta Energy Regulator, *Directive 009: Casing Cementing Minimum Requirements* (1990), http://www.aer.ca/documents/directives/Directive009.pdf.
55 Alberta Energy Regulator, *Directive 035: Baseline Water Well Testing Requirement for Coalbed Methane Wells Completed Above the Base of Groundwater Protection*, (May 8 2006), http://www.aer.ca/documents/directives/Directive035.pdf.
56 Alberta Energy Regulator, *Directive 044: Requirements for Surveillance, Sampling, and Analysis of Water Production in Hydrocarbon Wells Completed above Base of Groundwater Protection* (March 15, 2016), https://www.aer.ca/documents/directives/Directive044.pdf.
57 Alberta Energy Regulator, *Directive 083: Hydraulic Fracturing – Subsurface Integrity* (May 21 2013) http://www.aer.ca/documents/directives/Directive083.pdf.

- *Standard for Baseline Water-well Testing for Coalbed Methane/Natural Gas in Coal Operations.*[58]

AER regulations and directives relevant to groundwater protection are further described in Appendix B. Their focus is on minimizing risks to groundwater as a result of operations.

In addition Government of Alberta has a variety of requirements for monitoring, reporting and remediating spills from pipelines.[59]

b) Agriculture

For the agricultural sector the *Water Act and Environmental Protection and Enhancement Act* are augmented by the *Agricultural Operations Practices Act* (AOPA)[60] and the *Natural Resources Conservation Board Act.*[61] Regulatory approaches to protection of groundwater in the agricultural sector are further described in Appendix C.

AOPA and the *Standards and Administration Regulation* set out a variety of standards and setbacks for manure management.[62] Groundwater monitoring programs may be established and setbacks from springs and water wells are set at 100 meters.[63] The storage of manure and the required nature of the protective layer or liner are also prescribed.[64]

Broader manure management considerations, planning and risk assessment approaches are set out in *Environmental Risk Screening Tool for Manure Facilities at CFOs.* The focus of the tool is to inform inspectors in a transparent, consistent and science-based evaluation of the operation's environmental risk to groundwater and surface water.[65] Numeric risk scores are derived using

58 Government of Alberta, *Standard for Baseline Water-Well Testing for Coalbed Methane/Natural Gas in Coal Operations* (April, 2006), https://open.alberta.ca/publications/standard-for-baseline-water-well-testing-for-coalbed-methane-natural-gas-in-coal-operations. According to AER Directive 035 CBM wells above the base of groundwater protection must meet this *Standard*.
59 *Pipeline Act*, R.S.A. 2000, c P-15 and *Pipeline Rules*, A.R. 91/2005.
60 *Agricultural Operation Practices Act*, R.S.A. 2000, c. A-7.
61 *Natural Resources Conservation Board Act*, R.S.A. 2000, c. N-3.
62 *AOPA Standards and Administration Regulation*, A.R. 267/2001.
63 *Ibid.*, s. 7.
64 *Ibid.*, s. 9.
65 NRCB, *Environmental Risk Screening Tool for Manure Facilities at Confined Feeding Operations* Version 1.2 (September 2011), https://cfo.nrcb.ca/Portals/2/Documents/Forms-guides/ERST_Version_1.2.pdf .

“available information”. There is limited provision for “special considerations” where information is lacking or of low quality. [66]

The risk based approach is not formalized in regulation and there is limited ability to regulate grandfathered facilities.[67] The Board may make enforcement orders where “a person is creating a risk to the environment” under *AOPA*.[68] Emergency orders may also be made where there is a “significant risk to the environment”.[69]

Systematic sustained assessment and evaluation of risks at relevant scales is not mandated under this system. While some groundwater risk maps have been generated in the past this information is limited (in time and scale, using limited census data).[70] Further, the risk maps that have been generated appear to have limited relevance and no regulatory linkages to management actions to protect groundwater.

c) Municipal government

A detailed assessment of all municipal approaches to groundwater management would be a significant challenge, due to the large numbers of municipalities and the various types of bylaws and policies each may have that impacts groundwater. It is very relevant to note however that municipal planning and development decisions have extensive implications for hydrology and risks to groundwater supplies. As land managers municipalities play a central role in successful management and protection of groundwater resources.[71]

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66 *Ibid*., Appendix 3, p. 5. Subsurface knowledge and hydrogeological information may be largely absent in some cases.
67 For example, NRCB approval and risk assessment policies are generally only applicable to new and expanding CFOs. See NRCB *supra* note 68, p. 3 which states that the environmental risk screening tool will be used for review of applications for new and expanding facilities and as part of its response to some complaints.
68 *AOPA supra* note 63, s. 39.
69 *Ibid*., s. 42.1.
70 See section on “Threat and vulnerability mapping” *infra*. See also Alberta Agriculture and Forestry, “Agricultural Land Resource Atlas of Alberta – Groundwater Quality Risk for the Agricultural Area of Alberta” (2005), http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10339.
71 *Municipal Government Act* R.S.A. 2000, c. M-26, s. 640 sets out the power to regulate and prohibit and control the use and development of land and buildings in a municipality. It is notable that many environmental impacts that are “authorized” through decisions by municipalities are activities regulated by the *Water Act*. There are a variety of exemptions which may apply but there remains a fundamental disconnect between municipal development and groundwater resource protection. The capacity and technical knowledge required to understand development impacts is likely lacking in most instances.

Municipal decision making over groundwater management may be limited where other provincial agencies have decision making authority, such as the NRCB (Natural Resources Conservation Board) and AER.[72] Similarly, municipal decisions regarding groundwater may be contradicted or undermined by allocation decisions under the *Water Act.*

Conclusion regarding regulatory structures for groundwater

Sustainable groundwater management is challenged by isolated reviews of yield, a lack of information (uncertainty in decision making and risk assessment) and challenges in integrated planning and assessment across multiple jurisdictions.

Alberta's groundwater regulation is focused on incremental assessments of quantity and quality risks. Broader assessment of groundwater impacts and planning for sustainability have yet to be adopted as government policy. This, in turn, undermines efforts to protect groundwater and manage the resource sustainably. The multi-department nature of groundwater management in the province, while not unique, poses significant problems for holistic groundwater quantity and quality policy and regulation.

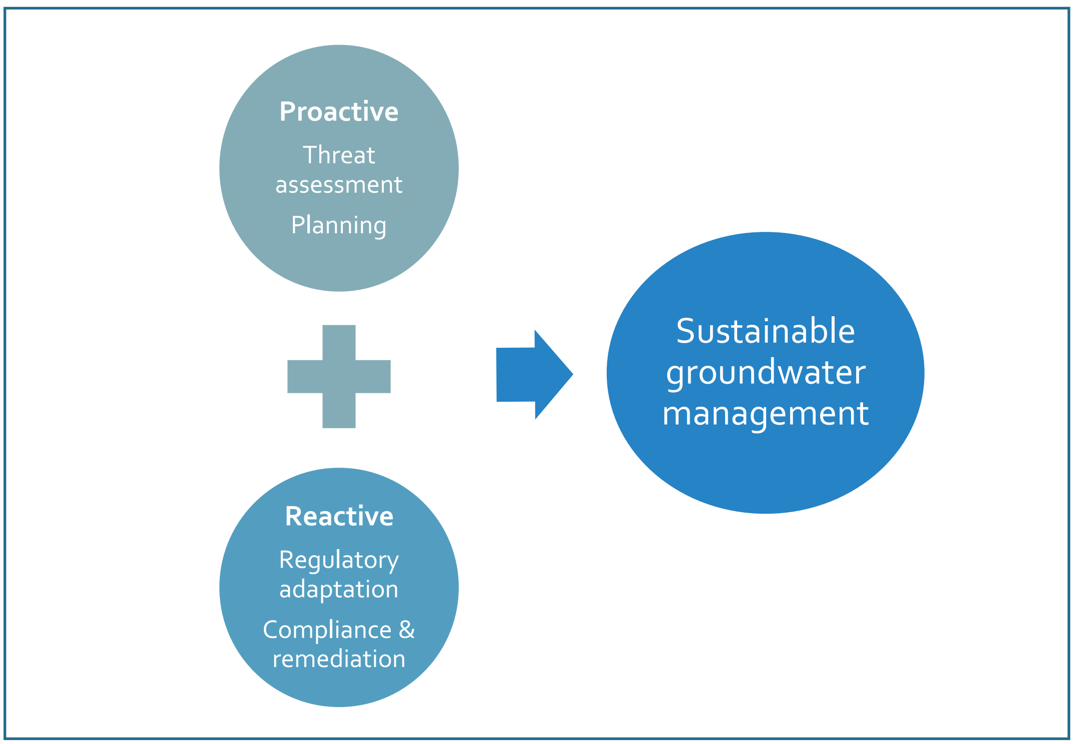
72 *Ibid.*, s. 619.

Part III: Policy elements for managing groundwater risks

To manage groundwater systems in a way that fosters long term sustainability of supply, protection of water quality and preservation of groundwater dependent ecosystems requires 1) assessment of potential risks, 2) precautionary planning and 3) management to minimize risks. This process must be iterative and focus on continuously improving knowledge of groundwater systems and adapting decisions and regulation to fit this new knowledge. In addition, where groundwater impacts are found to have occurred, there is a need to ensure prompt compliance and remediation action.

This part of the report outlines the elements which should be integrated into Alberta's groundwater management policy.

Figure 1: Proactive and reactive management of groundwater resources



Precaution is key: managing around uncertainty

Jakeman et al in Integrated Groundwater Management note:

> *Due to the inherent and often large uncertainties associated with managing groundwater systems, there is a need to communicate decision making in the context of uncertainty and, when possible, develop robust management strategies that perform well under a range of plausible conditions.*[73]

Even where uncertainty is identified and conveyed there is a need to be inherently precautionary in management decisions. For example, the efficacy of relying on current understanding of groundwater supplies will not suffice in a world where future climate variability brings significant uncertainty.[74] Overly simplistic risk assessment of the sustainability of supplies in light of climate change impacts must be avoided. In this regard, groundwater decision-making needs to be reframed in the context of "climate proofing" groundwater management in the province.

Green observes:

> *At a minimum, and in the absence of reliable projections of future changes in the hydrological variables, adaptation processes and methods can be implemented, such as improved water use efficiency and water demand management, offering no-regrets options to cope with climate change.*[75]

The most accurate and conservative methodology of forecasting supply should guide decision-making and then be augmented by the understanding of the potential impacts of future climate variability. Similarly forecasts and modelling for assessing risks (e.g. overland flooding and surface-groundwater communications) should use a precautionary approach.

Groundwater Assessment

Groundwater assessment must be guided by identifying risks at scales appropriate to relevant groundwater and environmental objectives. Relevant areas of assessment include watershed,

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73 A.J. Jakemen, O. Barreteau, R.J. Hunt, J.-D. Rinaudo, A. Ross, M. Arshad and S. Hamilton, "Integrated Groundwater Management: an Overview of Concept and Challenges", in J. Jakeman et al. (eds.), *Integrated Groundwater Management*, (2016) http://link.springer.com/book/10.1007%2F978-3-319-23576-9.
74 T. R. Green, "Linking Climate Change to Groundwater" in A.J. Jakeman et al. (eds.), *supra* note 77.
75 *Ibid*.

aquifer delineation, recharge mapping, source risks mapping, vulnerability mapping (pathway), and receptor mapping (anthropogenic and ecological). These nested mapping assessments should feed directly into planning documents, policy and decision-making.

a) Threat and vulnerability mapping

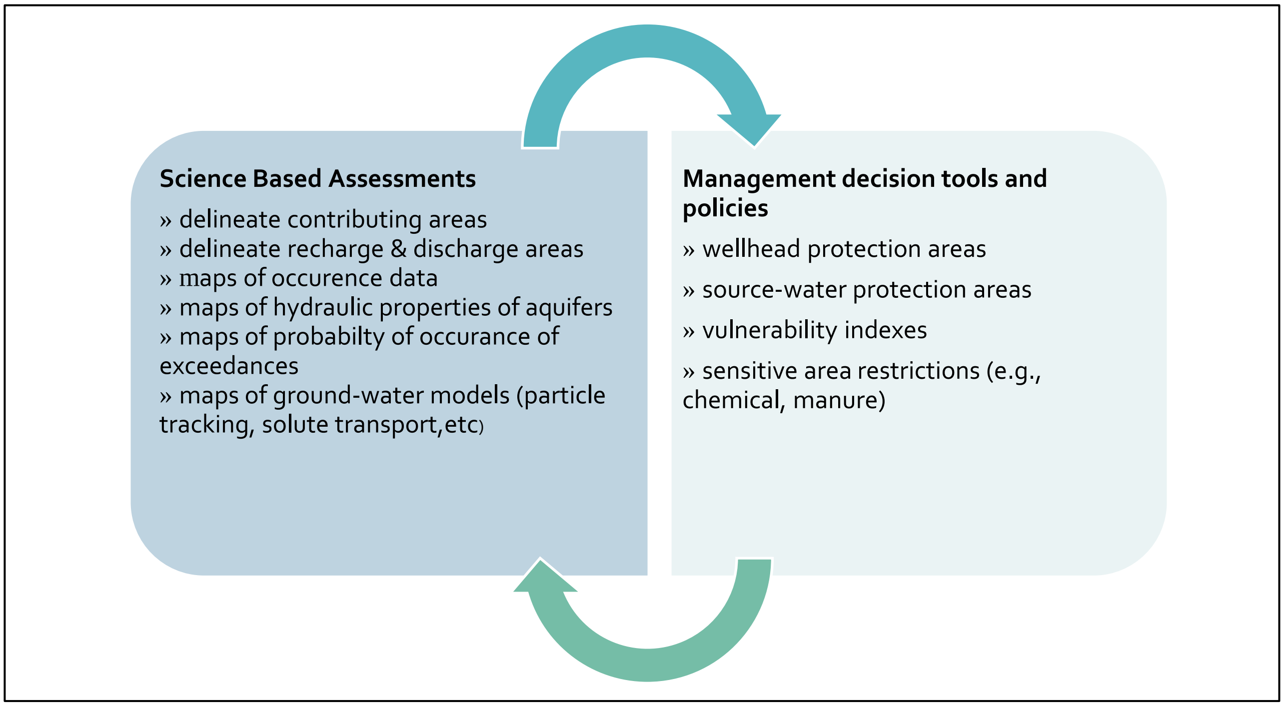
Site specific understanding of threats and vulnerability of groundwater resources is required to allow for effective and sustainable management. Focazio *et al.* note:

> *Clearly, ground-water vulnerability is a function not only of the properties of the ground-water-flow system (intrinsic susceptibility) but also of the proximity of contaminant sources, characteristics of the contaminant, and other factors that could potentially increase loads of specified contaminants to the aquifer and(or) their eventual delivery to a ground-water resource.*[76]

In this regard, it is essential to understand the hydrogeology and the nature of contaminant threats existing at appropriate assessment, planning and management scales. A scientifically reliable approach to groundwater mapping can then feed into management decisions (Figure 1).

76 M.J. Focazio, T.E. Reilly, M.G. Rupert and D.R. Helsel. Assessing Ground-Water Vulnerability to Contamination: Providing Scientifically Defensible Information for Decision Makers (U.S. Geological Survey Circular 1224, 2002), https://pubs.usgs.gov/circ/2002/circ1224/pdf/circ1224_ver1.01.pdf.

Figure 1: Groundwater assessment and decision making (adapted from Facazio et al., 2012)[77]



In Alberta, ongoing work by the Alberta Geological Survey has been leading to greater understanding of vulnerabilities in specific regions, however, ensuring this work translates effectively to drive decision making (discussed below) remains a challenge.[78] In addition, some regions have undertaken regional aquifer vulnerability mapping using surficial geology and aquifer depth and an agricultural intensity index (using "manure production, fertilizer use and agrochemical use, per unit area, based on 2001 Census of Agriculture data").[79]

While this information provides value in identifying relative risks to aquifers there is a need to significantly increase access to timely data and mapping of groundwater, identification and

77 *Ibid*., p. 29.
78 See, for example, Brian Smerdon, Lisa Atkinson and Alexandra Hughes, *Aligning Groundwater Mapping with the Scale of Regulation in the Fox Creek Area* (AGS, Water Tech conference, 7 April 2016).
79 Ongoing work by the Alberta Geological Survey has been leading to greater understanding of vulnerabilities at regional scales. For example, see Alberta Government map, *Groundwater Vulnerability: North Saskatchewan Region* (2010), http://aep.alberta.ca/water/programs-and-services/groundwater/science-and-knowledge/images/PGIP06.jpg. Also T. Cowen and T. Dash, Groundwater Vulnerability Map of Northern Alberta, (PFRA, unpublished, 2003).

mapping of specific risk pathways (e.g., abandoned well infrastructure), and integration with land use.[80] The scale of past vulnerability mapping is insufficient to discern more localized risks.[81]

Adaptive regulatory systems

The scientific assessment and mapping of groundwater vulnerabilities, while resource intensive, is essential to having informed groundwater decision-making and planning. The complexities in groundwater science and the resource intensive nature of data collection necessitate an adaptive approach to both management and regulation of the resource.

Where new information for discerning possible or probable impacts on groundwater quantity and quality become known there is a need to ensure regulatory authorizations, planning and compliance and enforcement actions change to align with the new information. Unfortunately, Alberta's current regulatory system is not well suited to continuous improvement and adaptation.

Assessment and planning that is undertaken may be insufficient or may not inform regulatory decisions to the extent they could. Those planning processes that are underway, such as drinking water safety plans, are not suited to assess risks to sustainable groundwater supply, groundwater quality protection or eco-hydrology criteria.

Grandfathered activities also largely avoid planning and management actions. Overall, there are a large number of activities that impact groundwater that either undergo limited assessment or no assessment related to risks to groundwater at all.

From a governance perspective, there remains no centralized (or decentralized) regulatory mandate to undertake source water protection planning, site specific vulnerability assessment, risk identification and mitigation conditions (including altered buffers and containment).

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80 Alberta Agriculture and Forestry (AF) and Agriculture and Agri-Food Canada (AAFC) initiated groundwater vulnerability mapping for the agricultural area of the province over ten years ago. Assessment is partially based on agricultural census data from 2001 and is in need of updating. See AF, *Agricultural Land Resource Atlas of Alberta – Groundwater Quality Risk for the Agricultural Area of Alberta*, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10339. This work has recently been modified by AEP and is presented for the three southern regional planning areas defined under the Land-use Framework. See AEP, *Provincial Groundwater Inventory Program*, http://aep.alberta.ca/water/programs-and-services/groundwater/science-and-knowledge/provincial-groundwater-inventory-program.aspx.

81 *Ibid*..

An effective groundwater policy framework will address these shortcomings. Targeted capacity and data collection regarding environmental impacts is particularly required. This requires investigation and implementation of tools for assessment and management of ecohydrology or groundwater dependent ecosystems (GDEs).[82] A framework for GDE identification was recently published and can be used as a model to guide development of policy and tools in Alberta.[83]

Timely compliance and remediation

To protect groundwater supplies, remedial action should be initiated where water quality moves beyond a range of natural variability and where water diversions result in unforeseen or adverse impacts on the environment and/or other users. For water quality, a clear policy around determinations of natural variability is needed in order to ensure a timely and effective compliance response.

A focus of the policy should be protection of non-saline aquifers. Where contamination is identified, an investigation and management response should be undertaken with the intention of near-term compliance.[84] Once groundwater quality has been observed to depart from a reference condition, compliance responses (by way of remedial orders) should be initiated.

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82 D. Eamus, Baihu FU, A.E. Springer, and L.E. Stevens "Groundwater Dependent Ecosystems: Classification, identification techniques and threats" in A.J. Jakeman et al. (eds.), *Integrated Groundwater Management* (2016) at pg. 330 citing F. Leaney, R. Crosbie, A. O'Grady, I. Jolly, L. Gow, P. Davies, J. Wilford and P. Kilgour, *Recharge and discharge estimation in data poor areas: Scientific reference guide*, (CSIRO, 2011), https://d28rz98at9flks.cloudfront.net/71940/Rec2011_035.pdf. Also Randall J. Hunt, Masaki Hayashi and Okke Batellan, "Ecohydrology and its relation to integrated groundwater management" in A.J. Jakeman et al. (eds.), *Integrated Groundwater Management* (2016), http://wcm.ucalgary.ca/hayashi/files/hayashi/hunt_etal_2016.pdf.

83 T.M. Doody, O.V. Barron, K. Dowsley, I. Emelyanova, J. Fawcett, I.C. Overton, J.L. Pritchard, A.I.J.M. Van Dijk and G. Warren, "Continental mapping of groundwater dependent ecosystems: A methodological framework to integrate diverse data and expert opinion", *Journal of Hydrology: Regional Studies* 10:61 (2017), http://www.sciencedirect.com/science/article/pii/S2214581817300319.

84 See, for example, M.N. Almasri "Nitrate contamination of groundwater: A conceptual management framework", *Environmental Impact Assessment Review* 27:220 (2007), https://staff-old.najah.edu/sites/default/files/Nitrate_Contamination_Of_Groundwater_A_Conceptual_Management_Framework.pdf.

PRECAUTIONARY APPROACHES TO WATER QUALITY AND QUANTITY ARE REQUIRED

There is a need to proactively identify baseline water quality and quantity in a manner that ensures protection and sustainability. An example of an initial attempt to regionally manage for groundwater outcomes is the *Lower Athabasca Region Groundwater Management Framework*.[85] The *Framework* illustrates the difficulty in setting regional groundwater quality objectives as aquifer variability is significant across formations.[86] As a result, reliance on site specific triggers and regulations is still required.[87]

The *Lower Athabasca Region Groundwater Management Framework* allows compromising of aquifers without clear regulatory response and compliance assurance. Impacts on aquifers may be the result of otherwise prohibited activities, such as releases under the *Environmental Protection and Enhancement Act*.

[85] Government of Alberta, *supra* note 55.
[86] *Ibid.*, pp. 26-27.
[87] *Ibid.*, pp. 25-26.

A recommended groundwater policy framework for Alberta

The Environmental Law Centre and Water Matters recommend unifying groundwater management and protection under a unified policy framework.

a) Principles

This framework should adopt the following guiding principles:

- Protection of groundwater resources in quality and quantity.
- Certainty and clarity of standards and process.
- Environmentally sustainable water management.
- Continuous improvement.
- Precaution.

Implementing these principles means tackling various barriers and gaps in existing policy. The Environmental Law Centre and Water Matters recommend adopting the following approach to move towards management that protects and sustains groundwater quantity and quality and improves regulatory responsiveness to groundwater risks and impacts.

b) Protect Groundwater Quantity

Ensure water quantity testing and modelling is sufficient to address long term groundwater sustainability, climate uncertainty, and ecohydrology. Recommended measures include:

i) Abandon the Q_{20} test in favour of more accurate modelling and yield testing.

ii) Adopt a system of addressing ecohydrology or groundwater dependent ecosystems (GDEs).

iii) Ensure any groundwater diversion renewals are accompanied by appropriate modelling (consistent with the above two measures).

iv) Formalize assessment and articulate uncertainty in relation to groundwater models and assessments (using relevant statistical methodologies).

v) Review permanent water licences to assess licence terms and adjust yield calculations as needed.

vi) Where licence conditions appear to limit the feasibility of reassessment of yields, ecohydrology impacts and diversion rates, seek voluntary compliance with revised diversion rates. Create a public registry where more appropriate diversion rates can be accessed.

vii) Integrate yield and GDE data into planning and regulatory decisions across jurisdictions by way of water management plans and regional planning.

viii) Introduce a precautionary factor to authorized diversions where evidence dictates.

ix) Identify high priority water yield areas based on groundwater sustainability criteria.

c) Protect Groundwater Quality

Ensure groundwater quality is maintained or improved. Recommended measures include:

i) Ensure risk and vulnerability mapping is scalable to inform decisions.

ii) Formalize groundwater risk assessment and mapping in a regulatory approach.

iii) Formalize groundwater risk management planning and responses through regulation (e.g., regional planning). This includes clear integration of groundwater risk assessments into authorization decisions by the province (under the *Water Act*, *Environmental Protection and Enhancement Act*, *Agricultural Operations Practices Act* and other legislation relevant to the Alberta Energy Regulator) and by municipal governments.

iv) Include both surface vulnerability and subsurface pathways in risk assessments.

v) Create an integrated risk database and registry that are geographically based, with data collected from various risk analyses undertaken by government and proponents.

d) Regulatory responsiveness to groundwater risks and impacts

The concept of "regulatory responsiveness" in relation to groundwater resources is focused on ensuring a robust system of ongoing monitoring, assessment and where needed, remedial and/or compliance action in relation to groundwater impacts. Groundwater regulatory responsiveness must be able to address threats to groundwater sustainability, whether that is related to well head vulnerability, land use, unsustainable yield, or subsurface vulnerabilities.

Groundwater protection encompasses a broad range of quality and quantity risks linked with various legislative mandates and legal and geographic jurisdictional constraints. There is a need to ensure compliance responsiveness exists across sectors and is timely in responding to monitoring and assessment data. Recommended measures include:

i) Set out regulatory compliance and enforcement policy for groundwater impairment.

ii) Set out authority to prescribe management responses to existing and new activities, regardless of risk level (i.e. ensure that source water protection planning is enforceable).[88]

e) Conclusion

A groundwater management policy framework must have multiple objectives, including:

- Ensuring yield is sustainable, both in terms of use and in terms of groundwater dependent ecosystems,
- protecting quality for intended uses and environmental quality,
- providing certainty to water users while recognizing a need to be adaptive to changing conditions and knowledge; and
- provide clarity and consistency in compliance and regulatory response where risks or impacts to groundwater are evident.

These objectives are best supported by publicly accessible information registry that sets out relevant assessment and mapping information. It is also essential that decision making across sectors, government departments and levels of government integrate groundwater assessment and planning.

Protection of groundwater will require ongoing commitment of resources and continuity in policy and regulatory leadership.

88 While the *Environmental Protection* and *Enhancement Act and Water Act* provide broad discretion to issue orders, often addressing impacts in a retroactive fashion, there is a need to ensure integration of enforcement across sectors. For example, NRCB compliance around confined feeding operation and risks associated with those to water.

Appendix A: Groundwater Basics and the Concept of Groundwater Yield.

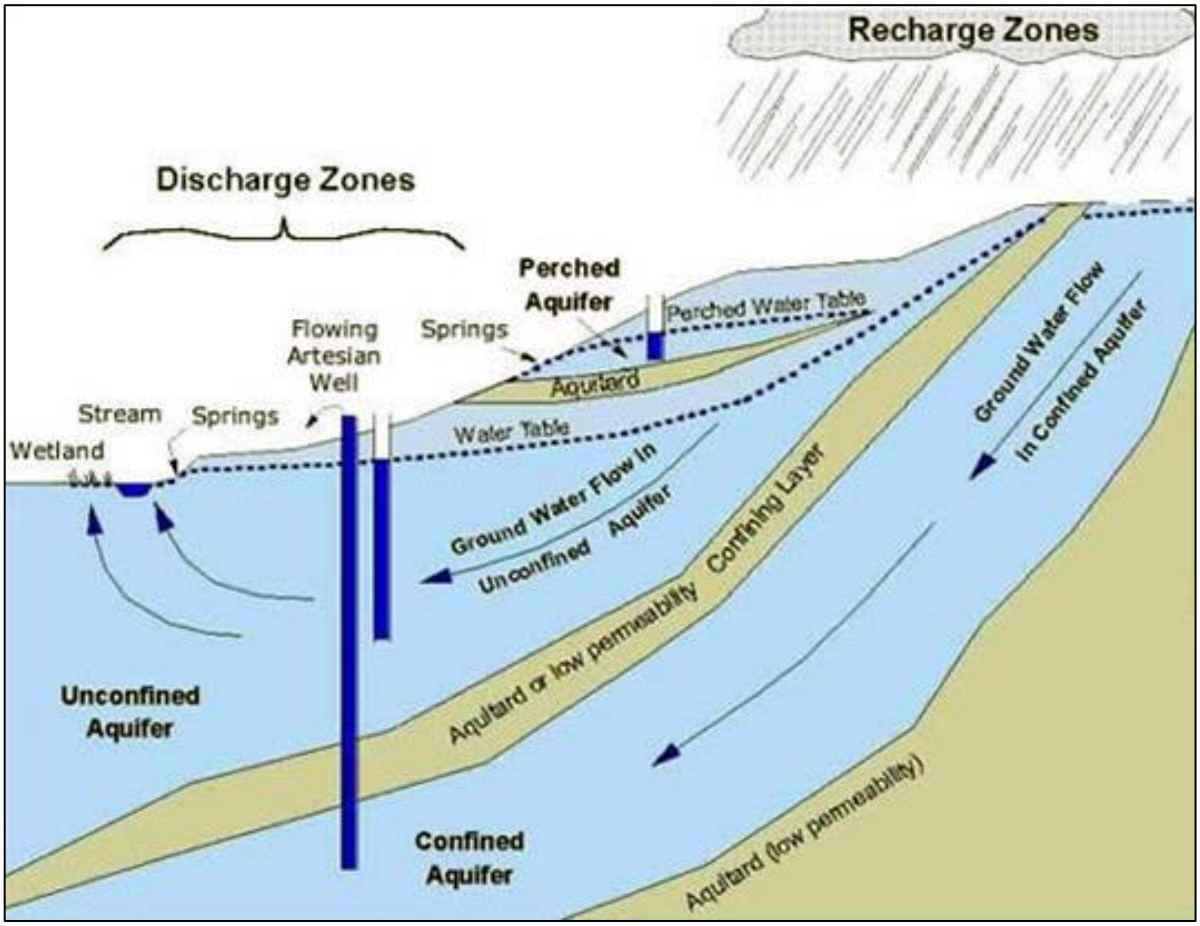
Groundwater Basics

When people speak of "groundwater", they are simply referring to water that occupies the pores in soil and rock, and the space below-ground that has been created by geological fractures. When these underground spaces hold sufficient water to be usable, they are referred to as aquifers, and the depth at which aquifers combine to create a continuous layer is referred to as the water table.[89]

A common misconception about groundwater is that it involves the movement of water deep below the ground that is somehow separate or isolated from surface water. While that may be true in some cases, there is often substantial connection between surface water and shallow groundwater, with water flowing between groundwater aquifers and streams, rivers or lakes. Rather than simply being fed by rain or snowmelt, a substantial portion of water in streams, rivers, wetlands or lakes is often provided by groundwater seeping into them. For example, during winter in Alberta groundwater inputs can contribute significantly to river and stream flow because, with the exception of relatively rare mid-winter snowmelt events, precipitation is stored on the landscape in the form of snow and there is little to no runoff into rivers and streams.

89 M. Berry, "A call for tougher groundwater management" ECOS 137 (Jun-Jul 2007): 28-30.

Figure 1: Groundwater discharge and recharge (Alberta Environment and Parks[90])



Another common misconception is that groundwater flows “downhill”, just as surface water does. However, because groundwater is moving through a three-dimensional soil or sediment matrix, while ultimately driven by gravity and moving from high points to low points, its pace and direction of movement at a particular location depend more on the nature of the material through which it is moving than on simple vertical gravitational force. For example, groundwater can move quite quickly through a buried lens of sandy soil or glacial till, but will move much more slowly through soil that is high in clay content. Consequently, the sandy soils or gravel can be referred to as having high hydraulic conductivity and soil with high clay content as having low hydraulic conductivity. Typically, groundwater will seek the path of least resistance, flowing in the direction of soils with the highest hydraulic conductivity.

90 Alberta Environment and Parks, *Groundwater*, http://aep.alberta.ca/water/programs-and-services/groundwater/default.aspx.

Just as in the tap in one's house, groundwater flow is dictated by changes in pressure: it follows a pathway from locations of relatively high pressure to locations of lower pressure. The pressure on groundwater will be the result of a combination of gravitational forces on the water itself and pressure exerted on the water by overlaying rock and soil. If there is no gradient in hydraulic pressure (i.e. differences in the pressure on water at different locations in an aquifer) then there will be no groundwater flow between those locations. Because the three-dimensional pressures upon an aquifer and the vertical and horizontal structure of the rock/sediment matrix within which an aquifer is located vary, the local pathways for groundwater also vary depending on location in the aquifer. Water moves laterally, up, or down, away from the area of high pressure and along the path of least resistance (i.e., the high-to-low pressure gradient).

Local soil porosity or conductivity and pressure gradients are generally factors that determine whether groundwater moves laterally, up, or down at any particular location, whether groundwater discharges into the bottom of a stream or lake that is connected to a groundwater aquifer, or whether water in a stream or lake flows into and recharges the aquifer. While broad regional directions of groundwater are from highlands to lowlands, local movement of groundwater is much less predictable because of the complex and variable pressure gradients and low hydraulic conductivity below ground. For this reason, and because groundwater cannot be measured easily and directly, it is difficult and expensive to accurately describe direction and rates of groundwater flow, both locally and regionally.

Where surface water and groundwater are often connected, the pumping of groundwater can affect surface water supplies and flow as well as dynamics of the aquifer itself. When groundwater pumping begins, the water coming from the well initially comes from storage in the aquifer adjacent to the well. Groundwater levels in the aquifer decline as part of the stored volume is depleted. Eventually, constant well pumping results in an increase in aquifer recharge from connected surface water or decreased aquifer discharge to surface water, and a new dynamic equilibrium is established in which water supplies in both the aquifer and connected nearby surface water are reduced to compensate for groundwater pumping.[91] It is the impacts of this storage depletion and decline in aquifer groundwater levels and the associated changes in dynamics of connected surface water that must be taken into account in planning for groundwater management and use, to avoid overexploitation.

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91 C.V. Theis, "The source of water derived from wells: essential factors controlling the response of an aquifer to development", *Civil Engineering* 10: 277-280 (1940).

Sustainable Yield

Groundwater flow provides valuable ecological functions that include feeding the baseflow of streams, balancing evapotranspiration or outflow losses from wetlands or lakes, maintaining land surface stability, and preventing the in-migration of saline or other poor-quality water into fresh aquifers.[92] In areas where there is a scarcity of surface water, or where surface water quality is low, groundwater is often also relied up for such things as urban or industrial water supplies, or permitting agriculture (via irrigation) in semi-arid or arid regions that otherwise would not support crops. However, an over-reliance on groundwater to support development may result in rapid declines in groundwater levels of shallow and deep aquifers, eventually leading to aquifer depletion, land subsidence, and saltwater intrusion and contamination of potable groundwater aquifers.[93]

In regions where overexploitation of groundwater resources is permitted, it is also often accompanied by overexploitation and diversion of surface water supplies and reductions in natural river flows. This substantially reduces the rates of natural recharge to groundwater aquifers and compounds the effects of overutilization of groundwater resources.

As with almost any natural resource that has value, there is a distinction between private and societal interests or value in groundwater. While the former is usually simple to identify, the latter can be assessed or determined according to a variety of criteria, including the adequacy of long-term public water supplies that anticipates changes in use or demand, the degree of equity in water use and allocation, and economic efficiency and sustainability of groundwater development.[94] However, despite that the sustainability of groundwater development is a function of the degree to which pumping results in environmental harms (e.g., reducing nearby surface water flows), this may or may not be considered in an assessment of economic efficiency of such development.

Where water access and use is strictly controlled via ranked water rights, general overutilization of surface and groundwater can impose on existing higher-priority water rights and ultimately

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92 J. van der Gun and A. Lipponen, "Reconciling groundwater storage depletion due to pumping with sustainability", *Sustainability* 2 (11): 3418-3435 (2010).
93 Y. Zhou, "A critical review of groundwater budget myth, safe yield, and sustainability", *Journal of Hydrology* 370: 207-213 (2009).
94 van der Gun and Lipponen, *supra* note 95.

reduce the economic benefits of water extraction.[95] It is for this reason that integrated water resource management should involve the assessment, planning, development, and monitoring of both surface water and groundwater together, as a single resource to be managed rather than as two apparently distinct resources.

The major risk associated with not approaching the management of surface water and groundwater in an integrated fashion is one of overexploitation: where use will not be sustainable, resulting in declines in the long-term supplies of both surface water and groundwater and the social, economic and environmental impacts that result from water shortages.

To rectify or avoid the problem of overexploitation of aquifers, there needs to be common understanding and agreement on how an aquifer's long-term supply capacity is measured and defined. Typically, this involves gaining an understanding of the geological structure and the three-dimensional hydraulic pressure gradients in an aquifer. Using this information, computer models are used to identify the direction and flow rates in an aquifer, and from these decisions can be made regarding the availability of groundwater for human use from a particular aquifer.

The amount of groundwater that can be sucked from a groundwater aquifer without causing substantial negative effects is generally referred to as "sustainable yield". However, unfortunately there are various definitions of "sustainable yield" that have been adopted, and they are often ambiguous rather than based on a standard definition that is rooted in fundamental groundwater flow principles and takes into account impacts of lowered groundwater levels and reduced storage.[96]

The most basic and narrow definition of sustainable yield is based on the understanding that groundwater withdrawal rates should not exceed the total recharge flow rates for an aquifer.[97] In its natural state, unaffected by groundwater pumping, an aquifer is in a state of approximate dynamic equilibrium, in which recharge, storage, and discharge are in balance. Typically, when pumping of groundwater from an aquifer begins, discharge from the aquifer to surface water declines and recharge to the aquifer increases (referred to as groundwater "capture" in response to pumping). When a new balance is eventually reached, groundwater recharge and discharge

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95 P. Domenico, *Concepts and Models in Groundwater Hydrology* (McGraw-Hill, New York, 1972).
96 F.R.P. Kalf and D.R. Wooley, "Applicability and methodology of determining sustainable yield in groundwater systems", *Hydrogeology Journal* 13 (1): 295-312 (2005).
97 van der Gun and Lipponen, *supra* note 95.

rates also will have reached new levels. Simply, the additional new discharge of groundwater resulting from the initiation of pumping must be balanced by an increase in recharge, a decrease in discharge, a decrease in storage in the aquifer (i.e., a drop in water levels), or a combination of the three.[98] This comprises what is generally referred to as the water balance.

A critical problem in groundwater use and management is the persisting belief that the maximum sustainable pumping rate for groundwater is equal to the long-term rate of natural recharge in an aquifer. This is often referred to as the "water budget myth".[99] "Sustainable pumping" has been a term used to describe when pumping of an aquifer can allegedly continue indefinitely without exhausting the reservoir, and is based on the assumption that the water budget components in the aquifer eventually adjust to a new steady-state and that progressive depletion of the aquifer stops.[100] However, continuous groundwater pumping results in drainage of an aquifer up until the pumping rate is balanced by both the decreased flow to surface water (lower groundwater discharge) and the induced increase in recharge (from nearby surface water to the aquifer), which in combination are generally referred to as groundwater "capture". Because the new steady-state that is reached depends on the ultimate changes in groundwater discharge <u>and</u> recharge (i.e., capture), the maximum sustainable pumping rate or yield is *not* the average natural groundwater recharge rate, but rather the maximum capture that can be produced. That is, yield is the sum of the reduction in aquifer discharge rates and the increase in induced aquifer recharge flow rates.

Unfortunately, determining the capture for an aquifer is not normally feasible, because complete data for an aquifer, including its recharge rates, are not usually available. It is for this reason that relying on an estimate of natural recharge rates as the primary or sole determinant of sustainability in groundwater pumping is false and incomplete. Hydrologic or groundwater sustainability is usually inappropriately interpreted as the prevention of the complete exhaustion of groundwater storage. Furthermore, all other *in situ* groundwater functions or roles are usually either considered to be secondary or are not considered at all.[101]

Although the amount of water in an aquifer will no longer be declining once the new steady-state balance is reached, the net flow of surface water to the aquifer may be greater than before the

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98 Zhou, *supra* note 96.
99 J.D. Bredehoeft, S.S. Papadopulos and H.H. Cooper, "Groundwater: The Water-Budget Myth" pp 51-57 in *Scientific Basis of Water Resources Management* (National Acadamies Press, Washington, DC, 1982).
100 J.F. Devlin and M. Sophocleous, "The persistence of the water budget myth and its relationship to sustainability", *Hydrogeology Journal* 13: 549-554 (2005).
101 *Ibid*.

new groundwater pumping began, and the flow rates in the aquifer and net discharge of groundwater to surface water likely will have declined. This is why surface water and groundwater should be managed in an integrated fashion. It is also why the generally accepted notion of *safe* or *sustainable* groundwater yield usually extends beyond simply considering limits on water supply for human uses (i.e., how much groundwater is available for extraction) to a broader question: Does increased withdrawal of groundwater, resulting in the removal of stored groundwater, increased recharge rates, and decreased discharge to surface water, cause unwanted or undesirable results?[102] If the response to this question is "Yes", or if this question is not being asked or cannot be answered, then it is likely that sustainable groundwater yield is not being assessed or considered in water resource or groundwater management plans or monitoring programs.

Thus, there is a distinction between *sustained* and *sustainable* yield. The notion of sustainable yield in the context of groundwater management should be consistent with the definition of "sustainable development" as adopted by the World Commission on Environment and Development to protect the long-term welfare of both humans and the environment[103]: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[104] Unfortunately, in practice the functional interpretation or application of "sustainable yield" of groundwater aquifers is usually indistinguishable from "sustainable pumping", because unwanted results, such as in nearby surface water, are not generally considered or incorporated into groundwater development planning or decision-making.[105] Too often, hydrological or groundwater "sustainability" is considered to be the operational equivalent to prevention of the exhaustion of groundwater storage[106], and all other groundwater functions, roles, or values – such as in maintaining base flows in streams and rivers or supporting wetlands and riparian ecosystems[107] - are either secondary or simply not considered at all. This is especially the case in regions where water scarcity is an issue, or where economic development options are perceived to be limited and short-term economics are the central

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102 J.D. Boyer and M. Maimone, in *A Statewide Planning Approach to Evaluating Groundwater Availability and Sustainable Yield* (South Carolina Water Resources Conference, 10-11 October 2012). Also Zhou, *supra* note 97.
103 Zhou, *supra* note 96. Also Devlin and Sophocleous, *supra* note 104.
104 *Report of the World Commission on Environment and Development: Our Common Future* (United Nations World Commission on Environment and Development, Oxford, UK, 1987). Also van der Gun and Lipponen, *supra* note 96.
105 van der Gun and Lipponen, *supra* note 95. Also Zhou, *supra* note 96.
106 van der Gun and Lipponen, *supra* note 95.
107 M. Sophocleous, "From safe yield to sustainable development of water resources - the Kansas experience", *Journal of Hydrology* 235: 27-43 (2000).

consideration in water resources management, despite that economic valuations of the ecological function of groundwater are usually incomplete or absent.

Because groundwater management is an operational pursuit concerning the allocation and use of a finite, quantifiable resource, genuinely sustainable groundwater yields must be defined and constrained by the supply and availability of the resource itself and the desire to avoid negative consequences of reduced groundwater and surface water supplies, rather than according to non-specific or vague word-based definitions.[108] Similarly, sustainable yield cannot be defined according to changes in simple metrics like aquifer storage or groundwater levels. For example, water levels are ambiguous and are not reliable indicators of whether an aquifer's pumped yield is sustainable over the long-term.[109] If our goal is to ensure our groundwater use is sustainable, then the local *in situ* functions of groundwater also must be understood, i.e., the functions fulfilled by groundwater when it is not pumped from an aquifer, as described above, in addition to the actual or potential use of groundwater as a source of water for municipal, agricultural or industrial activities.[110]

An analogue of sustainable groundwater yield that is defined according to our use and the long-term maintenance of *in situ* groundwater functions is sustainable forest management, which encompasses maintenance and enhancement of the long-term health of forest ecosystems (including protection of such things as wildlife habitat and water quality in streams) while providing on-going socio-economic benefits and opportunities that include the harvesting of trees.[111] Unfortunately, while the existing or potential function of an aquifer as a human water source is usually well known, the *in situ* functions and potential for an aquifer are not.[112] In the absence of a clear, operational definition of sustainable yield that not only considers our potential uses of groundwater but also extends to the avoidance of negative environmental, economic, or social consequences of decreased groundwater supplies caused by continued pumping, the overexploitation of aquifers poses a risk to not only the sustenance of many streams, wetlands, rivers, and lakes that rely on groundwater surface discharge, but also to the municipal, industrial and agricultural developments that proceed upon an assumption of stable, long-term groundwater supplies.

108 Kalf and Wooley, *supra* note 99.
109 *Ibid*.
110 van der Gun and Lipponen, *supra* note 95.
111 *Measuring our progress: Putting sustainable forest management into practice across Canada and beyond*, (Canadian Council of Forest Ministers, Ottawa, 2008).
112 van der Gun and Lipponen, *supra* note 95.

In Alberta, determination of sustainable yields from critical aquifers is identified as an important part of regional and basin-specific industrial and land-use planning, because it incorporates quantifying and developing an understanding of existing withdrawals, the interactions between groundwater and surface water supplies and withdrawals, and what level of groundwater withdrawals will be available in the long-term to support water-dependent regional development.[113] A major risk of groundwater withdrawal in the absence of legitimate assessments of sustainable yield is overexploitation, where the total rate of authorized withdrawals exceeds the long-term capacity of an aquifer to meet demands.[114] When this occurs, it is referred to as partial or total mining yields, rather than truly sustainable use that involves a balance between withdrawal rates and aquifer recharge.[115]

Definitions for sustainable groundwater yield (SGY) include the following:

- "Sustainable groundwater development at global and local scales is not the balancing of available aquifer storage to satisfy a single aim such as meeting water users' demands, but the maintenance and protection of the groundwater resource to balance economic, environmental and human (social) requirements."[116]
- "Sustainable water resource systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental, and hydrological integrity." (from the Task Force of the American Society of Civil Engineers, 1998)
- "How much water can be withdrawn from an aquifer system, where and for how long, with acceptable physical, economic, environmental, social, cultural, institutional, and legal consequences."[117]

The above definitions all hinge on the interpretation of what constitutes "acceptable" consequences, in terms of balancing the benefits gained by groundwater withdrawal with other costs or losses of benefits that are often not considered in the decision to approve or deny a grant of groundwater rights for pumping and use.

113 Boyer and Maimone, *supra* note 105.
114 Kalf and Wooley, *supra* note 99.
115 *Ibid*.
116 K.M. Hiscock, M.O. Rivett and R.M. Davison, "Sustainable groundwater development", pp 1-14 in K.M. Hiscock et al. (eds.), *Sustainable Groundwater Development* (Geological Society, London, UK, Special Publication 193, 2002).
117 W.C. Walton, and C.F. McLane, "Aspects of Groundwater Supply Sustainable Yield", *Groundwater* 51 (2): 158-160 (2013).

There are number of aspects of technical assessments of groundwater supply that are often overlooked, related to the fact that groundwater supply is bounded, evaluation of supply may be difficult, aquifer response times vary, supplies may be uncertain, and traditional groundwater management approaches may make sustainable management more difficult.[118]

The supply of groundwater is bounded by finite precipitation and physically bounded aquifer systems, and consists of five components that may not be feasible to quantify:[119]

i) Storage.
ii) Groundwater discharge to and recharge from surface water bodies.
iii) Evapotranspirative losses.
iv) Rejection of potential recharge in areas with shallow water tables.
v) Capture of groundwater from adjacent basins in connection with groundwater divide movements.

Because of the physically bounded nature of groundwater and the difficulty in quantifying supply, it is especially important that evaluation, management and utilization of the resource proceed cautiously and with care. Typically, evaluation of supply and sustainable yield are difficult because aquifers are heterogeneous and available data are limited. Where concentrated industrial extraction of groundwater results in unsaturated conditions in confining layers, it can result in declines in hydraulic conductivity of several orders of magnitude and thereby restrict vertical water movement.[120]

Modelling of the effects of these unsaturated zones in aquifers is difficult because determining unsaturated conductivity is uncertain and there can be partial reversals and delays in vertical flow from and into confined layers. In streams, modelling of groundwater recharge associated with induced infiltration is complicated because the latter varies with surface water temperature and dimensions of water bodies. Recharge rates also are higher during high-flow periods, because of streambed scouring, than during low-flow periods, when deposition of fine sediments reduces infiltration and groundwater recharge rates.[121] Further, in the event of declining water tables, the

118 *Ibid*.
119 *Ibid*.
120 *Ibid*.
121 S.E. Norris, "Aquifer tests and well field performance, Scioto River Valley, Near Piketon, Ohio: Part I", *Groundwater* 21: 287-292 (1983). Also S.E. Norris, "Aquifer tests and well field performance, Scioto River Valley, near

ground below a streambed becomes unsaturated and a reduction in vertical hydraulic conductivity further reduces recharge rates from streams.[122]

Further complicating sustainable groundwater management is the frequent disconnection between aquifer response times, management planning time-frames (which are often shorter than aquifer response times), and the timing and location of extraction wells.[123] For example, locating new wells in close proximity to groundwater surface recharge areas (e.g., streams) reduces the apparent equilibrium time that follows the increased withdrawals, relative to wells located further away from recharge areas.[124] Apparent response times in multi-layered aquifers will also vary, depending on whether withdrawals are from shallow or deep layers. A persistent problem in the evaluation of impacts of future withdrawals - especially in shallow, unconfined zones – is that those based on planning time frames can be substantially different than those based on aquifer response times. For this reason, the possibility of impacts beyond the planning time frame and the need for at least preliminary mitigation strategies to reduce those impacts should be part of the initial assessment and planning stages.[125]

When an aquifer is initially being developed as a water resource, a cost-effectiveness approach is typically applied to determining the location and yield of wells. As demand for groundwater approaches supply, strategies for resource maximization and optimization are increasingly considered. Maximization is aimed at avoiding excessive dewatering of aquifers by uniformly distributing water wells across withdrawals areas and throughout an aquifer system, including in some circumstances locating wells as close as possible to surface water. Unfortunately, this strategy does not minimize potential impacts of groundwater withdrawals to instream water uses, including on surface aquatic and riparian ecosystems.[126] Groundwater optimization and flow modelling are used to determine optimal or ideal well locations and withdrawal rates. Typically, this involves evaluating future withdrawal impacts on the basis of set constraints and varying current withdrawal schedules and patterns, rather than on the basis of extrapolation of withdrawals from existing wells and assessing impacts. Optimization strategies often involve such

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Piketon, Ohio: Part II", Groundwater 21: 438-444 (1983). Also P.E. Nortz, E.S. Blair, A. Ward and A. White, "Interactions between an alluvial aquifer well field and the Scioto River, Ohio", Hydrogeology Journal 2: 23-24 (1994).
122 R.G. Niswonger and D.E. Prudic, *Documentation of the Streamflow-routing (SFR2) Package to Insclude Unsaturated Flow Beneath Streams - a Modification to SFR1* (USGS, Reston VA, 2005).
123 Walton and McLane, *supra* note 120.
124 M. Sophocleous, "Interactions between groundwater and surface water: the state of the science", *Hydrogeology Journal* 10 (1): 52-67 (2002).
125 Walton and McLane, *supra* note 120.
126 *Ibid*.

options as limiting water table declines or streamflow depletions, enhancing artificial recharge, conservation and re-use, and conjunctive use of groundwater and surface water.[127]

Ultimately, estimates of sustainable groundwater yield should be based on the use of aquifer response times in modelling and water budgets for all aquifer and confining layers, involve the consideration of the possibility of intrusions or incursions of lower-quality groundwater into high-quality, fresh aquifers, and use existing pumping levels as a planning constraint. An effort also should be made to translate declines in water tables into quantifiable impacts, and to identify and reduce modelling uncertainties in creation of supply estimates. Such supply estimates should also include the quantification and assessment of the impacts of dynamic changes associated with groundwater capture on social, environmental, and economic benefits achieved from existing groundwater supplies. A critical part of reducing uncertainty in groundwater supply modelling, and therefore in groundwater management, is the adoption of scheduled, periodic post-audit validation of groundwater supply sustainable yield and revision and refinement as needed.[128] Above all, uncertainty in sustainable groundwater supply estimations should not hinder or provide a convenient barrier to continued efforts to improve groundwater management.

127 *Ibid*.
128 A. Hassan, *Validation, Proof-of-concept, and Postaudit Plans for the Groundwater Flow and Transport Model of the Project Shale Area*, (Desert Research Institute, Reno NV, 2004).

Appendix B: Summary of Groundwater regulation for Oil and Gas.

Regulation of hydrocarbon extraction and groundwater

A restructuring of administration of environmental laws related to energy development took place in 2012. The result is that the Alberta Energy Regulator (AER) administers the *Water Act*, *Environmental Protection and Enhancement Act*, the *Public Lands Act* and other regulations for energy related activities.

Regulations and Directives that are specific to AER and groundwater protection are set out below.

Note: Directives are documents that set out new or amended Alberta Energy Regulator ("AER") requirements or processes for implementation. Licensees, permittees, and other approval holders under the jurisdiction of the AER are required to obey all directives.

Standard/Directive	Approach to Groundwater
Standard: **Baseline Water Well Testing for Coalbed Methane Development**	The *Standard for Baseline Water-well Testing for Coalbed Methane/Natural Gas in Coal Operations*[129] ("*Standard*") to make baseline water quantity and quality testing from nearby water wells, prior to drilling energy wells, a mandatory regulatory requirement.[130] The *Standard* is aimed at: ● continued protection of Alberta's groundwater resources/supplies; ● facilitation of responsible CBM development; and ● consistency with the government's *Water for Life* strategy.[131]

129 Government of Alberta, *Standard for Baseline Water-Well Testing for Coalbed Methane/Natural Gas in Coal Operations* (April, 2006), https://open.alberta.ca/publications/standard-for-baseline-water-well-testing-for-coalbed-methane-natural-gas-in-coal-operations.
130 *Ibid.*, p. 2.
131 *Ibid*.

Standard/Directive	Approach to Groundwater
	The *Standard* also provides: ● consistent protocols for testing, sampling, and analyzing groundwater; ● scientific information to support achievement of the outcomes; and ● a regulatory basis for water well testing and baseline data collection prior to CBM development.[132] The *Standard* document also outlines the review timeline of baseline testing data, how Alberta Environment (AENV, *now AEP) handles water well complaints, and provides a list of the necessary procedural steps and other requirements when conducting tests (e.g., water well capacity, water quality data, etc.).[133]
Directive 009: **Casing Cementing Minimum Requirements**	The purpose of this guide is to outline casing cementing requirements in accordance with sections 6.080 and 6.090 of the *Oil and Gas Conservation Regulations*.[134] The key feature of this directive is that it explains how the intent of section 6.080(4) is to "ensure the protection of useable groundwater by the adequate cementing of production and/or intermediate casing in lieu of the requirement to set deeper surface casing".[135]
Directive 035: **Baseline Water Well Testing Requirement for Coalbed**	Directive 035 is what officially implemented the AENV's (*now AEP) Standard for Baseline Water Well

132 *Ibid*.
133 *Ibid*.
134 Alberta Energy Regulator, *Directive 009: Casing Cementing Minimum Requirements* (1990), http://www.aer.ca/documents/directives/Directive009.pdf.
135 *Ibid*., s. 1.

Standard/Directive	Approach to Groundwater
Methane Wells Completed Above the Base of Groundwater Protection	Testing for Coalbed Methane/Natural Gas in Coal Operations ("Standard"). This made baseline water-well testing mandatory for companies wanting to drill a new well or complete or recomplete wells for the purpose of producing coalbed methane (CBM) above the base of groundwater protection (BGWP).[136] Notably, the Standard currently only applies to the development of CBM above the BGWP (i.e. CBM wells are wells completed or recompleted in a coal seam). However, the EUB (*now AER) does "encourage" oil and gas companies to continue current practices of collecting baseline water quantity and quality data for water wells in close proximity to any energy development well prior to drilling and to submit these data to AENV.[137]
Directive 044: **Requirements for Surveillance, Sampling, and Analysis of Water Production in Hydrocarbon Wells Completed above Base of Groundwater Protection**	This directive details surveillance, sampling, and analysis of water production requirements and processes related to all hydrocarbon wells with completions above the base of groundwater protection (BGWP).[138] The term "hydrocarbon well" refers to conventional and unconventional wells (including oil sands wells) that are not part of a water recycle program.[139] (*Note: the directive uses the term "trigger volume", which refers to wells that produce water in excess of 30 m^3/month).

136 Alberta Energy Regulator, *Directive 035: Baseline Water Well Testing Requirement for Coalbed Methane Wells Completed Above the Base of Groundwater Protection*, (May 8 2006), http://www.aer.ca/documents/directives/Directive035.pdf.
137 *Ibid.*, s. 1.
138 Alberta Energy Regulator, *Directive 044: Requirements for Surveillance, Sampling, and Analysis of Water Production in Hydrocarbon Wells Completed above Base of Groundwater Protection* (March 15, 2016), https://www.aer.ca/documents/directives/Directive044.pdf.
139 *Ibid.*, s. 1.

Standard/Directive	Approach to Groundwater
	This directive outlines: • how to identify wells exceeding the prescribed trigger volume; • the actions required for wells exceeding the prescribed trigger volume (*this section includes the key requirements for the sampling and analysis of water production for hydrocarbon wells completed above the BGWP); and • how to resolve the production of accounting errors by using a specifically required process (*this includes a clarification section that states the AER will not accept truck tickets and arguments that third-party accounting providers are responsible as evidence of, or reason for, a water production volume accounting error).[140]
Directive 083**: Hydraulic Fracturing – Subsurface Integrity**	This directive sets out the AER's requirements for managing subsurface integrity associated with hydraulic fracturing subsurface operations. (*Note: this directive does not apply to thermal wells.)[141] These requirements intend to: • prevent the loss of well integrity at a subject well (a well at which a licensee proposes to conduct hydraulic fracturing operations); • reduce the likelihood of unintentional interwellbore communication between a subject well and an offset well;

140 *Ibid.*, s. 3.
141 Alberta Energy Regulator, *Directive 083: Hydraulic Fracturing – Subsurface Integrity* (May 21 2013) http://www.aer.ca/documents/directives/Directive083.pdf.

Standard/Directive	Approach to Groundwater
	• manage well control at an offset well in the event of inter-wellbore communication with a subject well; • prevent adverse effects to non-saline aquifers; • prevent impacts to water wells; and • prevent surface impacts.[142] This directive includes: • requirements to prevent the loss of well integrity at a subject well (section 2); • requirements for licensees to assess, plan for, and mitigate the risks of interwellbore communication with offset wells (section 3); • requirements to notify licensees of at-risk offset wells related to hydraulic fracturing operations (section 3); • requirements to protect non-saline aquifers from hydraulic fracturing operations conducted at depths less than 100 metres (m) below the base of groundwater protection (BGWP) (section 4); • increased vertical depth restriction for hydraulic fracturing operations near water wells (section 5); • increased vertical depth restriction for hydraulic fracturing operations near the top of the bedrock surface (section 6); • pumping-volume restrictions and provisions to setback distances for nitrogen fracturing operations for coalbed methane (section 7); and

142 *Ibid*., s. 1.1.

Standard/Directive	Approach to Groundwater
	• requirements to notify the ERCB (*Energy Resources Conservation Board, now Alberta Energy Regulator) about hydraulic fracturing operations (section 8).

Other Groundwater Relevant Policies and Guidelines

Water is sometimes pumped into oilfields to help maintain reservoir pressure, which in turn helps maintain oil production. This process is called oilfield injection.[143]

The Water Conservation and Allocation Policy for Oilfield Injection (2006) and its corresponding *Guideline* support the conservation and management of water and prevent excess use of water during enhanced oil recovery operations. The *Policy* and *Guideline* include specific environmental outcomes that support the goals of the *Water for Life Strategy*.

Policy / Guideline	Approach to Groundwater Comment
***Water Conservation and Allocation Policy for Oilfield Injection* (2006)**	The *Policy* goal is to reduce or eliminate allocation of non-saline (fresh) water for oilfield injection, while respecting the rights of current licence holders.[144] The *Policy* sets out key operating principles: • It takes a 'place-based' approach to water management, guiding industry working in water-short areas, and areas with development pressures to maximize water conservation efforts; • New projects within water-short areas that propose to use non-saline water must demonstrate that every feasible option has been evaluated and only non-saline water resource use will prevent stranding oil resources;

143 Alberta Environment and Parks, *Groundwater: Regulation and Policy*, http://aep.alberta.ca/water/programs-and-services/groundwater/regulation-and-policy/default.aspx.
144 Government of Alberta, *Water Conservation and Allocation Policy for Oilfield Injection* (2006), https://open.alberta.ca/publications/0778531447.

Policy / Guideline	Approach to Groundwater	Comment
	• When no "feasible alternative exists", consideration should be given to delaying projects until new technology or alternative water sources are available; • In <u>all cases</u> where new oilfield injection projects are proposed for water-short areas, environmental risks need to be carefully weighed against economic benefits of the project; and • If fresh water must be used, a risk-based process, performance measures and economic analysis must be considered in choosing the water source for oilfield injection.[145] Regulatory goals are set out and actions articulated to minimize potable water use.[146] These actions ended in 2015. Policy effectiveness has not been reported on. With respect to policy application, effective January 2006, this *Policy* applies (and continues to apply) to the allocation of both non-saline groundwater and surface water resources. It applies to all *Water Act* applications and to the renewal of existing term licences. Holders of permanent licences (issued under the *Water Resources Act*) are "encouraged" to cooperate with the intent of this *Policy* and its *Guidelines*, and according to the specific conditions of their licences.	

145 *Ibid*., p. 3.
146 *Ibid*., p. 6.

Policy / Guideline	Approach to Groundwater	Comment
Water Conservation and Allocation Guideline for Oilfield Injection **(2006)**	This Guideline provides direction for regulatory agencies and developers where the use of non-saline water resources for oilfield injection. The Guideline describes and guides the tiered risk based approach to assessment injection programs and decision making process.[147] Outstanding questions about the risk based system and how groundwater systems are determined to be "at risk" remain in light of insufficient data. The policy refers to the Groundwater Evaluation Guidelines to determine the non-saline potential of groundwater sources.[148]	

147 Government of Alberta, *Water Conservation and Allocation Guideline for Oilfield Injection* (2006), https://open.alberta.ca/publications/water-conservation-and-allocation-guideline-for-oilfield-injection, p. 5.
148 *Ibid.*, p. 38.

Appendix C: Summary of Groundwater regulation for Agriculture

Agriculture and groundwater risks

The *Water Act* and *Environmental Protection and Enhancement Act* are further augmented by the *Agricultural Operations Practices Act (AOPA)*[149] and the *Natural Resources Conservation Board Act*.[150]

Program / Policy / Guideline	Approach to Groundwater
Agricultural Operation Practices Act (AOPA)	*AOPA*[151] deals with groundwater through a variety of means (primarily driven by risk assessment and point of impact mitigation of risks). Sections relevant to ground and surface water protection include: • Section 13 - Approval, registration required; • Section 14 - Authorization Required; • Section 15 - Manure, composting materials, compost application; • Section 17 - Variance; • Section 19 - Approval notification, directly affected parties; and • Section 20 - Considerations on Approvals.
Confined Feeding Operations (CFOs): Permitting Approval Policy	The application review process is outlined in the NRCB's Approval Policy (*Operational Policy 2016-7*) and cites a risk based approach to groundwater and surface water protection.[152] This policy adopts by reference the *Environmental Risk Screening Tool for Manure Facilities at Confined Feeding Operations*.

149 *Agricultural Operation Practices Act*, R.S.A. 2000, c. A-7.
150 *Natural Resources Conservation Board Act*, R.S.A. 2000, c. N-3.
151 *AOPA*, *supra* note 147.
152 Natural Resources Conservation Board, *Approvals: Operational Policy 2016-7* (January 26, 2016), https://cfo.nrcb.ca/Portals/2/Documents/Policies/Approvals_Policy_updated_May_8_2018.pdf.

Program / Policy / Guideline	Approach to Groundwater
	High and moderate risk sites may attract more conditions to mitigate risks.[153] There is no indication of what type of risks will result in a refusal to grant a permit or expansion.
Standards and Administration Regulation[154]	This is the primary regulation which states set back distances for manure management and requirements for nutrient management (Nitrogen based). Groundwater monitoring programs may be established and setbacks from springs and water wells are set at 100 meters.[155] The storage of manure and the required protective layer or liner are also set out.[156]
Compliance and Enforcement Policy (CEP)(Operational Policy 2016-8)	The CEP recognizes groundwater or surface water contamination as a 'serious situation'. Serious situations are given a high priority by the NRCB and are addressed immediately. These situations typically involve a release of manure that has caused or is causing a risk to surface water or groundwater, or situations in which such a release is imminent.
Environmental Risk Screening Tool for Manure Facilities at CFOs (Version 1.2 – Sept 2011)	The ERST provides a qualitative assessment of risk at individual CFOs. The focus of the tool is to inform inspectors in a transparent, consistent and science-based evaluation of the operation's environmental risk to groundwater and surface water.[157]

153 *Ibid.*, s. 2.1
154 *AOPA Standards and Administration Regulation*, A.R. 267/2001.
155 *Ibid.*, s. 7.
156 *Ibid.*, s. 9.
157 NRCB, *Environmental Risk Screening Tool for Manure Facilities at Confined Feeding Operations* Version 1.2 (September 2011), https://cfo.nrcb.ca/Portals/2/Documents/Forms-guides/ERST_Version_1.2.pdf.

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	The ERST uses a numeric scoring system to screen risk at a facility.[158] To assess facilities in a consistent manner, many evaluation factors are used in the hazard potential and pathways sections. A numeric value is assigned to each factor that reflects the level of potential environmental risk.[159] Risks to groundwater and surface water are considered separately for a facility, rather than having a single total score for the facility. This allows for focusing corrective action on the specific pathway at risk or facility causing the risk. This risk assessment is guided by "available information" and a lack of information may be incorporated to a degree into the risk assessment. [160]

The risk-based approach is not formalized in regulation and there is limited ability to regulate grandfathered facilities.[161] The Board may make enforcement orders where "a person is creating a risk to the environment" under *AOPA*.[162] Emergency orders may also be made where there is a "significant risk to the environment".[163]

158 *Ibid*., p. 2.
159 *Ibid*., p. 2.
160 *Ibid*., Appendix 3, p.5. Subsurface knowledge and hydrogeological information may be largely absent in some cases.
161 For example, NRCB approval and risk assessment policies are only generally applicable to new and expanding CFOs. See NRCB *supra* note 155 which states that the environmental risk screening tool will be used for review of applications for new and expanding facilities and as part of a response to some complaints.
162 *AOPA*, *supra* note 147, s. 39.
163 *AOPA*, *supra* note 147, s. 42.1.