Water and Oil:
An Overview of the Use of Water for Enhanced Oil Recovery in Alberta

March 2014

Effective March 29, 2014, the Alberta Energy Regulator (AER) has taken over jurisdictional responsibility for water and the environment with respect to energy resource activities in Alberta from Alberta Environment and Sustainable Resource Development.

As part of this jurisdictional transfer, the title page of this guide now carries the AER logo and a new publication date. However, no other changes have been made.

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march 2004

Alberta
GOVERNMENT OF ALBERTA

introduction

In Alberta, there are a number of uses for water that result in it being removed from the water cycle for a long period of time. These include the deep well disposal of industrial wastewaters, water used for washing salt caverns and water used for the enhanced recovery of oil through water and steam injection processes.

During the public consultation phases of *Water for Life: Alberta's Strategy for Sustainability*, held in 2002-2003, Albertans raised a number of concerns regarding the sustainability of various water uses, particularly water used for the enhanced recovery of oil (oilfield injection).

Albertans are concerned about reductions in the availability of useable water (i.e., losses from the active water cycle) at a time when drought conditions impact other water users in the province.

background

How much water is the oil and gas sector currently licensed to use?

Alberta Environment issues licences for water use in Alberta and keeps records of all the water that is allocated. Water allocations are based on the expected maximum amount that an applicant may require annually. Therefore, total allocations do not represent actual water use or actual amounts of consumption. Up to the end of 2001, Alberta had allocated over 9.4 billion cubic metres of water annually for a variety of uses. Allocations from surface water sources account for 98 per cent of this total; the remaining two per cent are from groundwater sources.

For 2001, the oil and gas sector was licensed to use 4.6 per cent of all the water allocated in Alberta; less than half (1.9 per cent) of this water is allocated for water and steam injection operations. By comparison, the agriculture sector (including irrigation) was licensed to use the largest amount of water of any economic sector, at approximately 46 per cent. Municipal water supplies accounted for 11 per cent.

How much water does the oil and gas sector actually use specifically for enhanced oil recovery?

Of the total water allocated in the province, the oil and gas sector actually uses less than half of one per cent for water and steam injection processes (enhanced oil recovery). Water used for these purposes has declined from 88.7 million cubic metres in 1973 to 47.5 million cubic metres in 2001 – 37 million cubic metres of this was non-saline (fresh) water, 10.5 million was saline or brackish water. (Source: *Water Use for Injection Purposes in Alberta* report, Alberta Environment, 2003, www.waterforlife.gov.ab.ca/docs/geowa_report.pdf)

Actual volume of water diverted and used for enhanced oil recovery in 2001 was 47.5 million cubic metres. 37 million cubic metres was from non-saline (fresh) sources.

How much is 37 million cubic metres of water?

- *Two days of flow of the North Saskatchewan River at Edmonton*
- *Seven and a half per cent of the volume that can be stored in the Oldman Reservoir, or about the top 1.6 metres of the reservoir*

How is the diversion of water regulated?

According to Alberta's *Water Act*, agricultural, industrial, municipal and other non-domestic water users must apply to Alberta Environment for a licence to divert and use an annual allocation of water. In Alberta, water is allocated on the principle of *first-in-time, first-in-right* for both surface and groundwater resources. This principle, which has existed since 1894, means that water diversions are prioritized according to the seniority of a licence, regardless of use. (The older the licence, the higher the priority).

For households that are not part of a municipal water system, up to 1250 cubic metres of water per year can be used, from any water source accessible at that location.This household water use is a statutory right and has the highest priority of all water diversions.

Before any application to divert water is approved, Alberta Environment reviews the application to ensure existing water users' rights are protected, that water is available to meet the needs of the applicant and the impacts on the aquatic environment are minimized.

There are several regulations and policies that oil and gas operations must follow when diverting and using water in their operations. For example, Alberta Environment regulates the diversion of non-saline groundwater in the white zone of the province through the "Groundwater Allocation Policy for Oilfield Injection Purposes."

This policy requires oil and gas operations to investigate non-water alternatives and alternative sources of water before an application to use non-saline groundwater is made, and outlines quantity limitations and time limit restrictions on water diversions.

Why are Albertans concerned about this issue?

During the public consultation phases of *Water for Life: Alberta's Strategy for Sustainability*, held in 2002-2003, Albertans raised a number of concerns regarding the sustainability of various water uses, particularly water used for the enhanced recovery of oil (oilfield injection).

» ***Albertans are concerned about sustainable water supplies.*** Population growth, droughts and agricultural and industrial development are increasing demand and pressure on Alberta's water supplies. Water conservation and more efficient water use are important for all Albertans, and all sectors, in order to ensure that we have a sustainable water supply to support continued prosperity and healthy ecosystems.

The quantity of water used for enhanced oil recovery activities constitutes a relatively small portion of the available and allocated provincial water supplies. However, Albertans remain concerned that enhanced oil recovery and injection removes water from the active water cycle.

» ***Albertans are concerned about the security of their local water supplies.*** Many individual Albertans have concerns for the safety and long-term sustainability of their own water supplies. Nearly 600,000 rural residents in Alberta depend on groundwater from a single well or aquifer for their household needs, and many farms also use groundwater to water livestock.

In general, household and farm wells are not monitored for declining performance and users may not be prepared for fluctuations in water availability. On the other hand, larger scale industrial water diversions used for oilfield injection maintain extra "standby" wells that can be brought on-stream rapidly if a water well casing or pump failure occurs. Industrial users monitor the performance of wells and aquifers frequently to ensure an uninterrupted water supply. Some industrial operations build pipelines to larger rivers that can provide a sustainable water supply during drought periods.

There is potential for conflict between individual water supplies and larger scale users. Bigger operations can afford better infrastructure to drought-proof the water supply for their operations. Many Albertans have expressed concern that the existence of industrial scale water diversions increases their own risk of facing a water shortage.

Rural municipalities and counties have also expressed concerns regarding industrial scale water diversions in rural communities. Many rural municipalities operate community water distribution systems and have concerns about long-term sustainability of the water supply. Local governments also feel they have a responsibility to represent and protect their residents from developments over which they have limited control.

» ***Albertans want a balance between economic growth and a healthy environment.***
More than 50 per cent of Alberta's production of conventional light oil each year is now supplied by enhanced oil recovery projects. Royalties from oil and gas help to provide the funds needed to deliver core public programs in Alberta such as health, education and infrastructure.

The use of water in enhanced oil recovery projects is currently the most common practice and considered the most economic option by the industry. As with all water uses however, many Albertans have concerns on the effects to the environment and aquatic ecosystems. They want to be assured that water is being used responsibly.

overview of enhanced oil recovery processes

Enhanced oil recovery processes increase the amount of oil produced from a well. In most cases, water is injected into a well to increase the pressure and force out some of the remaining oil that can no longer be pumped. Water can also be used to recover oil from oilsands through the injection of steam to heat and liquefy the crude bitumen.

There are two broad categories of enhanced oil recovery processes –

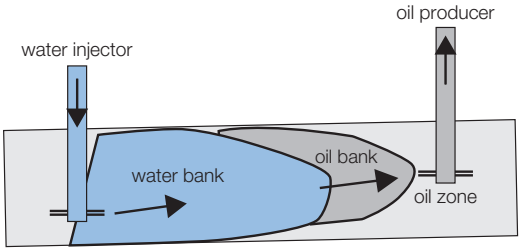
» Conventional enhanced oil recovery
» Thermal enhanced oil recovery

Conventional Enhanced Oil Recovery

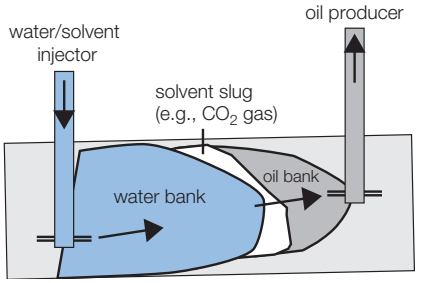
Conventional enhanced oil recovery, also known as secondary recovery or the water flood method, is a process in which saline or non-saline water is injected to displace the remaining oil in a pool by increasing or maintaining the fluid pressure. In some cases, an additional injectant such as a solvent or a gas is added along with the water. This is called a tertiary process.

In conventional enhanced oil recovery, the volume of liquid produced partly determines the volume of water required for injection. The liquid produced is often a mixture of oil and saline water that is found naturally mixed in oil reservoirs.

Secondary or "Water Flood" Enhanced Oil Recovery Process



Conventional "Tertiary" Enhanced Oil Recovery Process



Thermal Enhanced Oil Recovery

Thermal enhanced oil recovery is a process that injects water as steam directly into oilsand deposits or conventional heavy oil pools. The steam heats the bitumen, making the heavy oil more liquid so that it can flow to production wells.

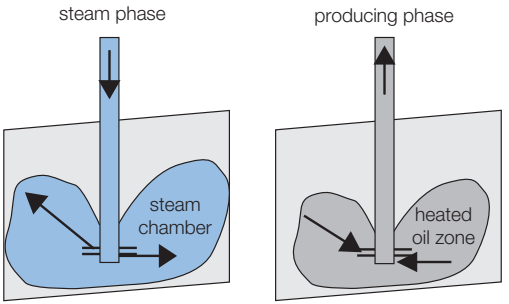
There are two types of thermal enhanced oil recovery projects –

» cyclic steam stimulation
» steam-assisted gravity drainage

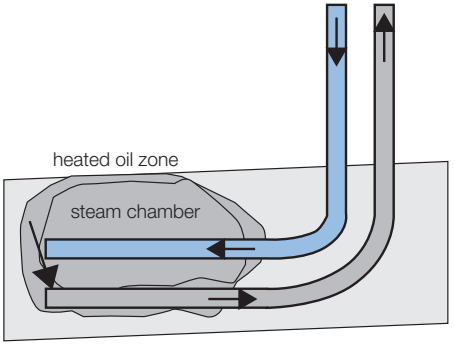
To recover bitumen or heavy density oil using the cyclic steam stimulation method, intermittent amounts of steam are injected into a well. The steam heats the area near the well, reducing the heavy oil thickness and allowing drainage to begin. Using this method, steam injection and production of crude bitumen is through the same single well.

The Steam-Assisted Gravity Drainage, or SAGD, method involves a continuous injection of steam into oilsands through a horizontal injector well, which makes the bitumen liquid enough to drain into a lower production well. The process requires precisely aligned horizontal pairs of wells, with the steam injector well drilled five to 10 metres above the production well.

Thermal “Cyclic Steam Stimulation” (CSS) Process



Thermal “Steam-Assisted Gravity Drainage” (SAGD) Process



Definitions and descriptions in the above section are derived from a report prepared by GEOWA Information Technologies Ltd. in 2003, and from internal Alberta Environment documents prepared by Environment and Energy and Utilities Board staff. Please refer to the glossary at the end of the report for additional definitions.

facts and figures about oilfield injection water use

Water Use and Trends

In 2001, the actual volume of source water diverted for the purpose of enhanced oil recovery was 47.5 million cubic metres. Of this amount:

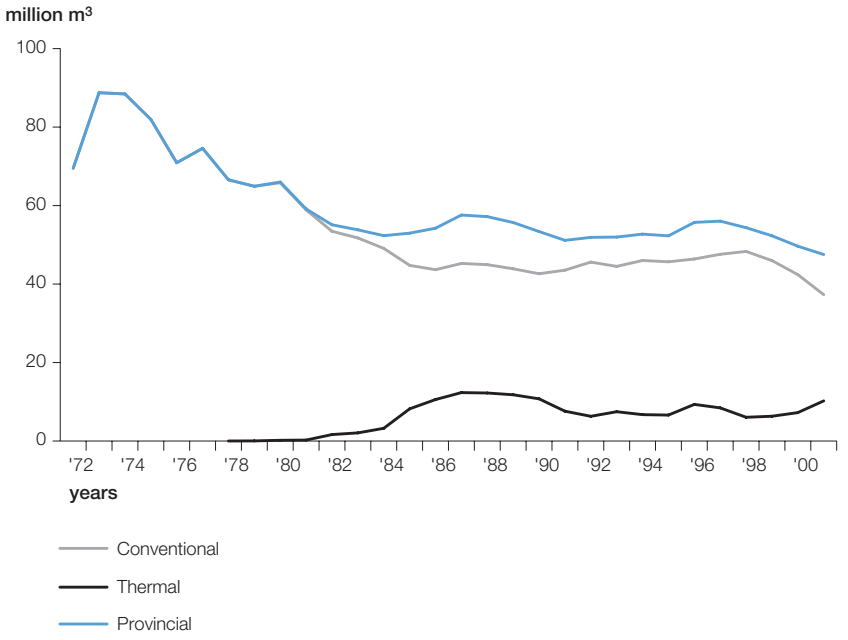
» 37.1 million cubic metres (78.1 per cent) was from non-saline, or fresh, sources and
» 10.4 million cubic metres (21.9 per cent) was saline water.

Surface water sources provided 26.9 million cubic metres (72.5 per cent) of the total non-saline water while the remaining 10.2 million cubic metres (27.5 per cent) was sourced from groundwater.

Recent advances in technology have enabled the use of some saline groundwater in steam generation processes, as a portion of the source water needed for steam injection. This may help reduce the use of surface water and non-saline groundwater resources in the future.

In summary, there has been a decrease in the overall amount of water used during the past 30 years, but an increase in the amount of saline water used.

Total Source Water Used



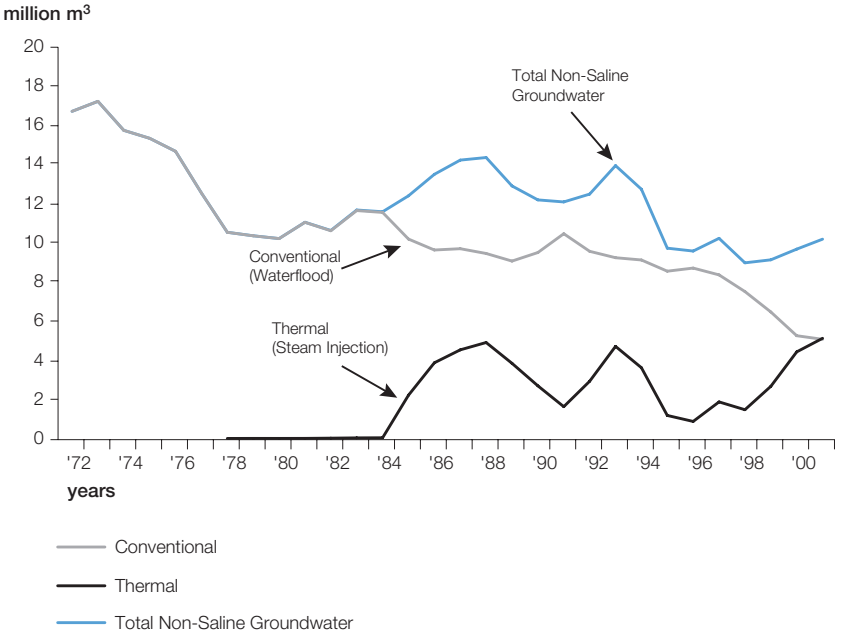
Source water can be:

- *surface water*
- *saline groundwater*
- *non-saline groundwater*

In 2001, a total of 276.4 million cubic metres of water was injected for enhanced oil recovery operations in Alberta. Approximately 83 per cent (228.9 million cubic metres) of this water was produced water, recovered together with oil from oil reservoirs. The remaining 17 per cent of water injected (47.5 million cubic metres) was new source water, including both saline and non-saline water sources.

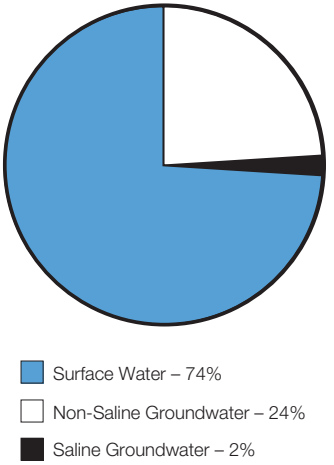
The graph above illustrates the volumes of source water used for thermal and conventional oil recovery operations in Alberta.

Enhanced Oil Recovery – Non-Saline Groundwater Use 1972-2001

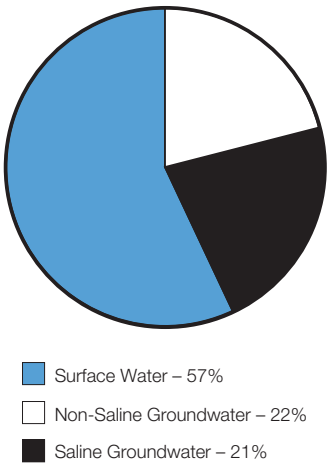


Since the mid 1970s, the use of non-saline groundwater and surface water for conventional oilfield injection has been declining in Alberta overall. However, uses for thermal oil recovery are expected to increase due to rapid expansion of the oilsands and heavy oil sectors.

1972 Oilfield Injection Total Volumes – Source Water
Total Diversion = 69,497,060 m^3



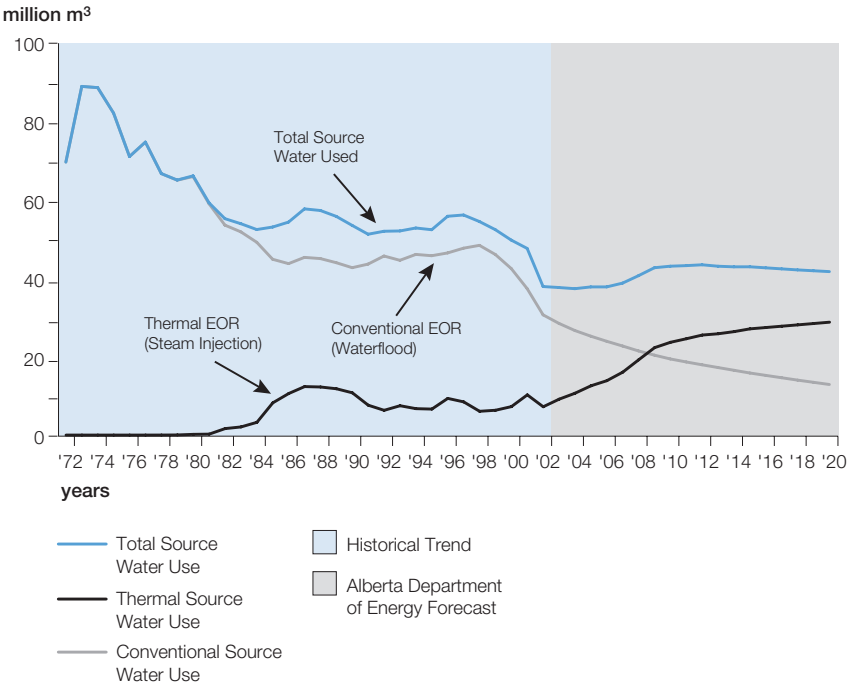
2001 Oilfield Injection Total Volumes – Source Water
Total Diversion = 47,525,748 m^3



Forecasting future water use for oilfield injection is difficult. There are many unknown variables, such as future oil prices and advances in technology, that could have a major impact on the pace of new development and the economic limits of current enhanced oil recovery projects.

Alberta Energy has forecasted water needs based on the best available information. While these projections contain inherent uncertainties, the overall trends of Alberta's oil and gas industry is a decline in conventional oil production (and thus a decline in water use) and an increase in bitumen production from thermal enhanced oil recovery projects (increasing water use).

Enhanced Oil Recovery – Total Source Water Use (Historical and Forecast)



Oilfield Injection Water Use: The Provincial Perspective

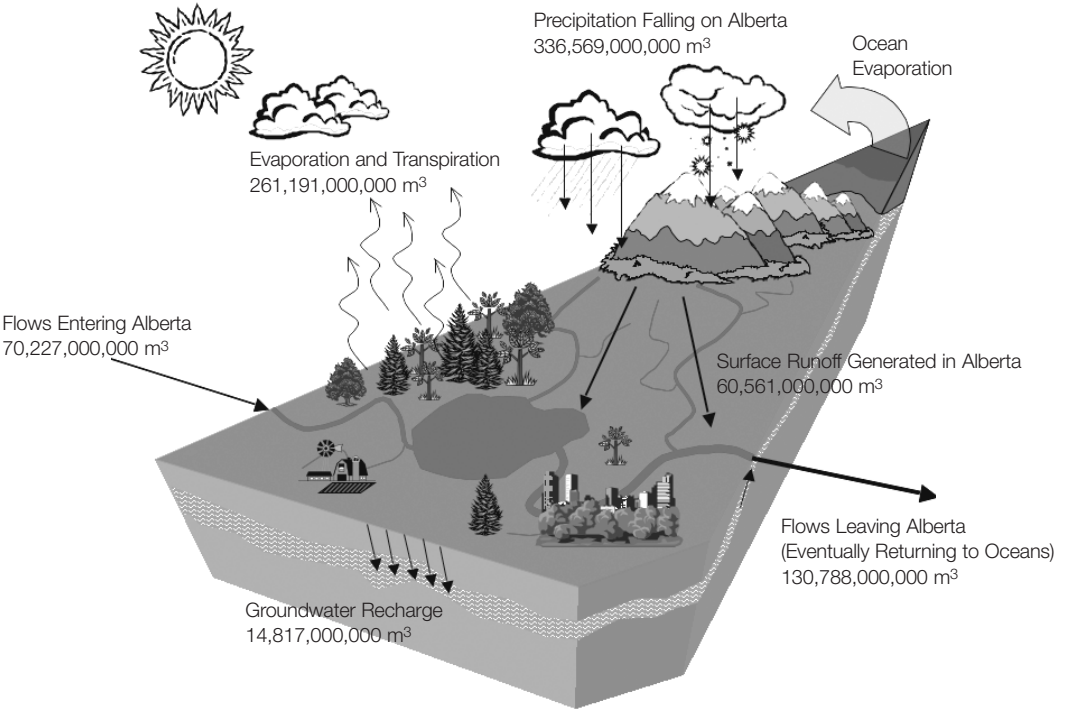
Alberta's water supply is derived from rain and snow that falls over the province and is driven by evaporation from the ocean. On average, Alberta receives a mean annual precipitation of about 510 millimetres, which is equivalent to about 336 billion cubic metres of water. The vast majority of this precipitation (more than 77 per cent) returns to the atmosphere through evaporation and transpiration, while about 4.5 per cent contributes to groundwater recharge. The remaining portion (18 per cent) becomes surface run-off.

The volume generated from surface run-off flowing into streams and rivers is equal to about 60 billion cubic metres of water per year. This is equivalent to about 90 millimetres of water spread over the entire area of the province. In addition to the streamflow generated in Alberta, there is another 70 billion cubic metres of streamflow that enters Alberta from other provinces and from the United States. As a result, there is a combined total of 130 billion cubic metres of water, on average, that leaves the province as streamflow each and every year.

With these figures in mind, the 37.1 million cubic metres of fresh water that was used for enhanced oil recovery in 2001 represents:

- 0.029 per cent of average streamflow in Alberta each year; or
- 0.014 per cent of the annual volume that returns to the atmosphere due to evapotranspiration; or
- 0.011 per cent of average annual precipitation that falls on Alberta; or
- 0.25 per cent of the estimated annual amount that recharges groundwater.

Alberta's Average Annual Water Balance



A Local Perspective

Since oilfield injection essentially removes water from the active water cycle and prevents any potential further use of the water to downstream users, this practice can potentially lead to local impacts. Although the total quantity of water used for enhanced oil recovery represents a relatively small amount when compared to the overall provincial water supply picture, it may seem considerable in areas where water availability is stressed. For this reason, site-specific water use licences are only issued by Alberta Environment after a complete review of the potential local impacts of a proposed water diversion, with licence conditions that protect existing water users.

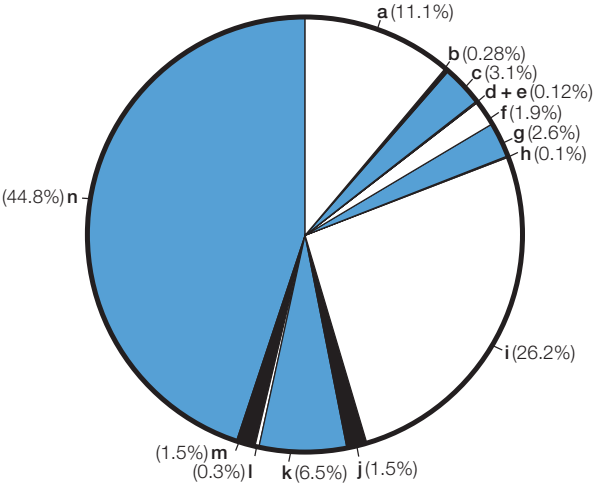
Comparison with Other Sectors

Up to the end of 2001, Alberta had allocated over 9.4 billion cubic metres of water annually for a variety of uses, with allocations from surface water sources representing 98 per cent of this total. Reliance on groundwater overall is therefore relatively small, although it does provide a considerable amount of the domestic water supplies for rural and agricultural users.

The three largest allocations of water in Alberta are for irrigation (44.8 per cent), industrial cooling purposes (26.2 per cent) and municipal water supply (11.1 per cent).

Enhanced oilfield recovery has been allocated up to 169 million cubic metres, or about 1.9 per cent of total allocations from combined surface and groundwater sources.

Water Allocations in Alberta by Specified Purpose (Surface plus Groundwater, based on existing licences as of 2001)

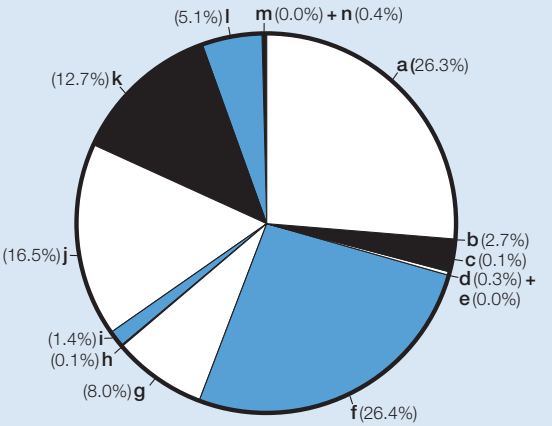


Please note: the legend corresponds to both pie charts

- **a** Municipal
- **b** Recreation
- **c** Water Management
- **d** Other Purpose Specified by the Director
- **e** Wildlife Management
- **f** Injection (Oil Recovery)
- **g** Industrial (Oil, Gas, Petroleum)
- **h** Drilling (Developing Oil/Gas Wells)
- **i** Commercial (Cooling)
- **j** Agricultural
- **k** Commercial
- **l** Fish Management
- **m** Habitat Enhancement
- **n** Irrigation

Total Licensed Volumes = 9,443,795,000 m^3
(9,259,492,000 m^3 surface water;
184,303,000 m^3 groundwater)

Groundwater Allocations (Representing 2% of Overall Water Allocations)



How has groundwater been allocated?

Surface water is the source for 98 per cent of all water allocations, with groundwater providing only two per cent of the overall allocations.

Oilfield injection and municipal water supply are the single largest licensed users of groundwater in Alberta, each at roughly 26 per cent of the total groundwater allocation.

However, it should be noted that household use (one of the largest uses of non-saline groundwater), does not require a licence under the Water Act, *and therefore, is not included in the allocated total of 184,303,000 m^3.*

The actual use of non-saline groundwater for oilfield injection in 2001 (10,157,000 m^3) was a relatively small portion (5.5 per cent) of the allocated total volume of groundwater.

addressing the issue

In the summer of 2002, Alberta Environment initiated a cross-ministry working group to begin gathering information needed to understand the issue of oilfield injection uses of water in Alberta.

The working group, with representatives from Alberta Environment, Alberta Energy and the Energy and Utilities Board compiled water use data from Alberta Environment and Energy and Utilities Board records. The working group commissioned a report to provide an analysis of oilfield injection water use data and recommendations for data management and reporting. The full report, *Water Use for Injection Purposes in Alberta*, is available online at www.waterforlife.gov.ab.ca

Following the release of that report in September 2003, the Government of Alberta appointed a stakeholder Advisory Committee on Water Use Practice and Policy to lead a policy review.

With representation from landowners, the oil industry, municipalities, agriculture, environmental groups and the public-at-large, the review will focus on ways to improve water conservation and reduce demand.

Information on the Terms of Reference and the membership of the Advisory Committee is available online at www.waterforlife.gov.ab.ca

The Advisory Committee is scheduled to provide a report, outlining its recommendations, to the Minister of Environment in spring 2004.

For more information about the advisory committee, contact:
David Trew, Alberta Environment
4th Floor, Oxbridge Place
9820-106 Street
Edmonton, AB T5K 2J6
Tel: 780.427.3029
Fax: 780.422.6712
(outside of Edmonton, dial 310-0000 for toll-free connection)
E-mail: david.trew@gov.ab.ca

glossary

Allocation » When water is permitted to be redirected for a use other than for domestic purposes, it is referred to as an allocation. Agricultural, industrial and municipal water users apply to Alberta Environment for a licence to use a set allocation of water. This water licence outlines the volume, rate and timing of a diversion of water.

Bitumen » Best described as a thick, sticky form of crude oil, so heavy and viscous that it will not flow unless it is heated or diluted with lighter hydrocarbons. At room temperature, it is much like molasses.

Cyclic Steam Stimulation (CSS) » A type of thermal recovery process that uses steam injection. The injected steam heats the area near the well, reducing the heavy oil thickness and allowing drainage to begin. Using this method, steam injection and production of crude bitumen is through the same well.

Disposal water » Produced water from oil, gas and crude bitumen production that is injected into deep underground formations approved for disposal by the Energy and Utilities Board (EUB).

Enhanced oil recovery (EOR) » A process in which a substance, typically water (saline, non-saline, produced and recycled) is injected into oil reservoirs to increase and maintain the reservoir pressure so that more oil can be extracted. The two main types of enhanced oil recovery are water flooding, in which water is pumped into conventional oil field reservoirs, and injection of steam into heavy oil deposits. Enhanced oil recovery operations do not include oil sands mining operations.

EUB (Energy and Utilities Board) » The EUB is a provincial quasi-judicial, independent body created by the Government of Alberta to ensure that the energy resources of the province are responsibly developed and that the natural monopoly around the transportation of these resources has reasonable tariffs. For instance, it is specifically mandated to ensure optimum recovery of the province's oil, gas, and crude bitumen resources.

Evapotranspiration » The combination of evaporation from the surface of soils and vegetation, plus the transpiration of water through plant leaves and vegetation.

Green Zone » The mainly public, forested lands of northern Alberta and the Eastern Slopes that are not available for agricultural development, other than grazing.

Hydrologic cycle (water cycle) » The hydrologic cycle is the process by which water evaporates from oceans and other bodies of water, accumulates as water vapor in clouds and returns to oceans and other bodies of water as rain and snow, or as run-off from this precipitation or as groundwater.

Injectant » A fluid (water, wastewater, solvent, steam, gas, etc) approved by the EUB for injecting into an enhanced oil recovery project or disposal well.

Injection » Either water flooding or steam injection.

Licensed wells » Deep, generally saline wells that are licensed by the EUB (all wells greater than 150 metres deep are licensed by the EUB.)

Make-up water » Water (not produced water) that is injected into an oil-bearing zone to enhance the operation of an enhanced oil recovery project. Make-up water is new water needed to replace the volume of oil and gas produced in conventional enhanced oil recovery projects, and replace volumes of produced water that are lost in the treatment and steam generation processes for thermal in-situ projects (oil or crude bitumen). Source water is another name for make-up water.

Non-saline water » Water with less than 4000 mg/L of total dissolved solids (TDS). Often referred to as fresh water.

Oilfield injection » Processes in which water, with or without another injectant (hydrocarbon solvent or CO2), is injected through wells into conventional hydrocarbon reservoirs to increase or maintain the reservoir pressure so that hydrocarbon recovery is increased. Oilfield injection also includes processes in which water is injected as steam through well(s) into oilsand deposits or conventional heavy oil pools to lower the viscosity of the crude bitumen so that it can flow to a production wellbore.

Primary recovery » Oil flows or is pumped to the surface from an oil pool without using any injectant.

Produced water » Water that is produced along with hydrocarbons (oil, gas, and crude bitumen) from a well. Produced water is separated from the oil and gas and is measured and reported to the EUB. Produced water volumes from every oil and gas production well are included in the EUB Production Injection Database.

Recycled water » The total quantity of water injected at a project less the source water.

Return flow » Water that has been diverted under the terms of a *Water Act* licence for a specific purpose but does not get consumed in the process and is returned to the environment. Typically, this is water that results from a temporary use, such as water cycling through a cooling pond, but it can also result from consumptive uses such as municipal wastewater that is treated and returned to the environment.

Saline groundwater » Groundwater that has more than 4000 mg/L of total dissolved solids (TDS).

Secondary recovery » Also known as waterflood, injecting water into the oil pool to maintain pressure and displace oil.

Source water » See make-up water definition.

Start-up water » The large initial water volume required for injection to a new conventional enhanced oil recovery project to replace oil and gas removed. The large volumes of water needed at steam plants to initiate thermal recovery of bitumen is also referred to as start-up water. The ongoing requirements for make-up water in conventional and thermal enhanced oil recovery projects are usually at lower rates than are needed during start-up of the project.

Steam-Assisted Gravity Drainage (SAGD) » A term used to describe a type of thermal recovery process used for the in-situ recovery of bitumen from oilsands. The process consists of continuous injection of steam into the oilsands through a horizontal injector well, which lowers the viscosity of crude bitumen enough that it drains into a lower production wellbore. The process requires precisely aligned horizontal well-pairs with the injector well drilled five to 10 metres above the production well.

Steam injection » A process in which steam is injected into oilsand deposits to reduce the bitumen viscosity to allow it to flow and be produced to surface. Steam injection can include either SAGD or CSS methods of enhanced oil recovery.

Tertiary recovery » Includes all other methods or techniques used to increase the amount of oil recovered. Secondary and Tertiary recovery are together referred to as enhanced oil recovery.

Water flooding » A term used to describe a conventional enhanced oil recovery process in which water is pumped into a well to maintain the reservoir pressure so that hydrocarbon recovery is enhanced.

Watershed » A watershed is the area of land that catches precipitation and drains into a larger body of water such as a marsh, stream, river or lake.

White Zone » The settled regions where agriculture is the most significant land use, including the grasslands and parklands of southern and central regions, and the Peace Country in the north.