Water, the environment and human health

'Health and Environment'
University of Lethbridge
November 2, 2016

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Irrigation and Farm Water Branch
Alberta Agriculture and Forestry

Government of Alberta

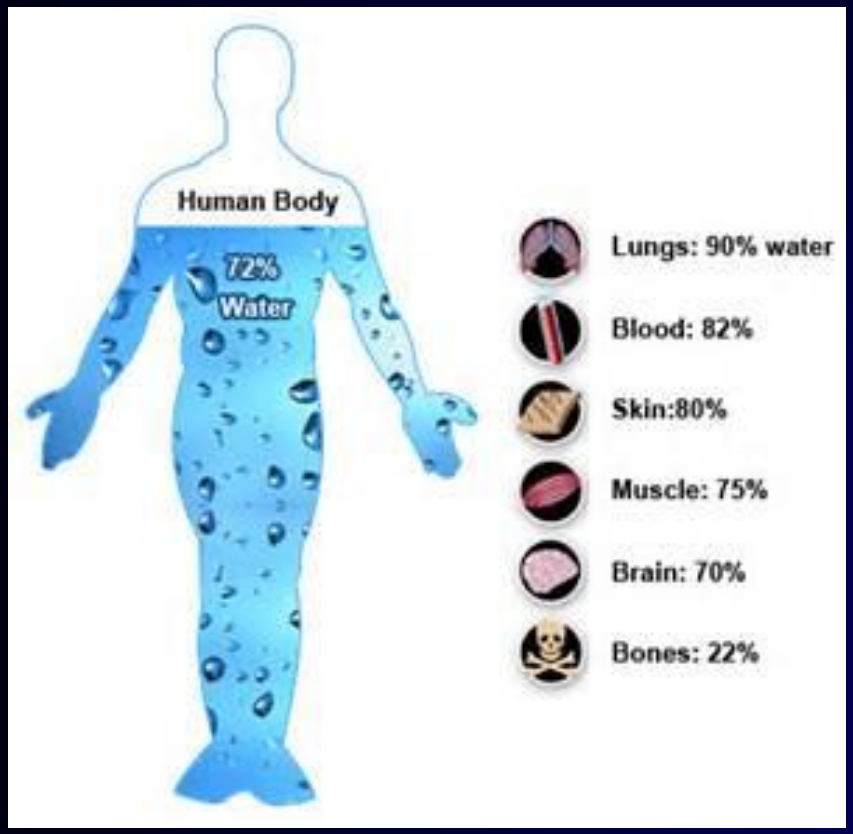
Outline

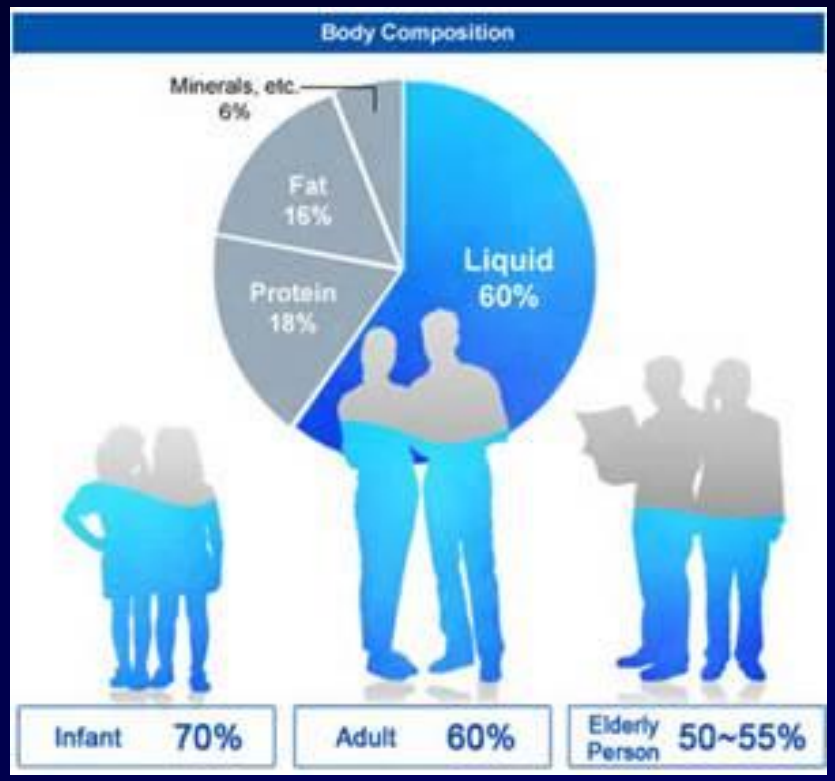
- Introduction to water and food production
  - Water supply
  - Water management
  - Water quality
  - Focus on local (irrigation)
- Ecological extremes that impact water
  - 2013 Flood and Aquatic Invasive Species

Water Supply

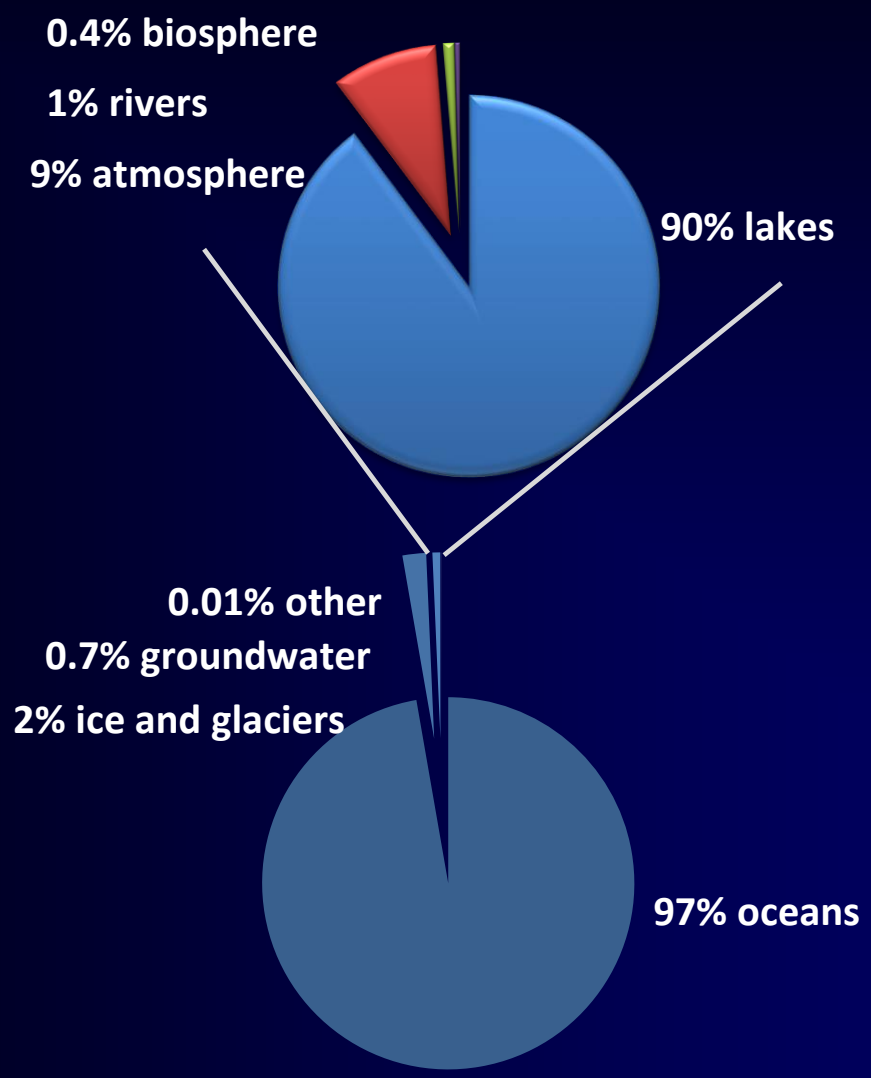
Water is critical to human health

How much water is in a human?





How much freshwater is there?



Globally,
<1% freshwater

Global agriculture

Agriculture is the single greatest interaction of humankind with our physical environment.

Land
40% of the land surface used for agriculture; one-third used for crops, two-thirds used for livestock.

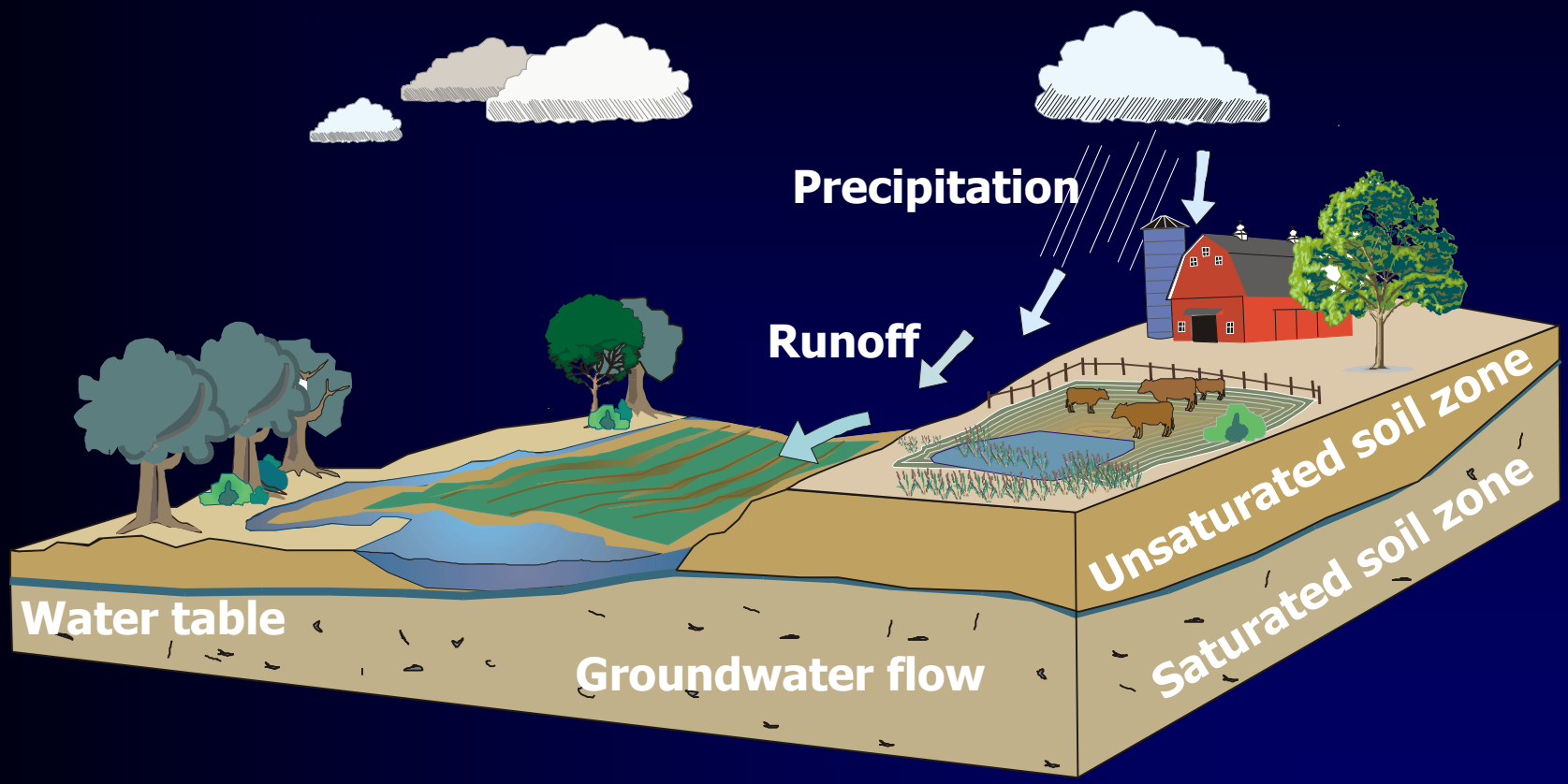
Water
70% of water withdrawn used for agriculture.

Population Increase
-> 9.7 billion (2050)
Currently, ~850 million malnourished/hungry

Land and Water

- Land was the major focus during the 20th Century.
- Water will be the dominant focus of the 21st Century.

The water cycle: Surface and groundwater

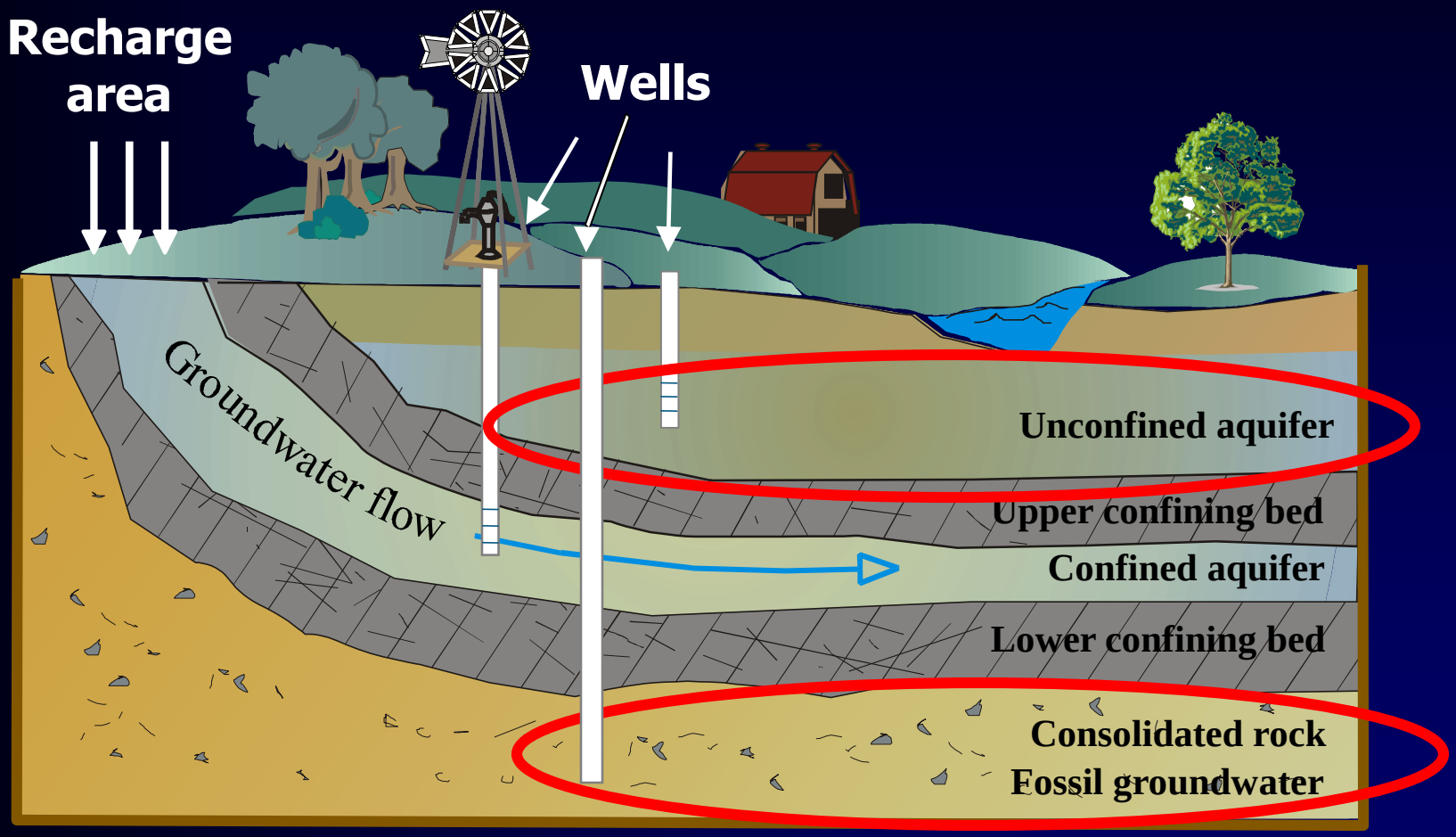


Land and water are interconnected!

Groundwater

- Many countries currently rely on “Fossil” groundwater for irrigation.
- These groundwater resources are being depleted at an increasingly rapid rate.
- And once they are gone from the ground, they are gone forever.

Groundwater



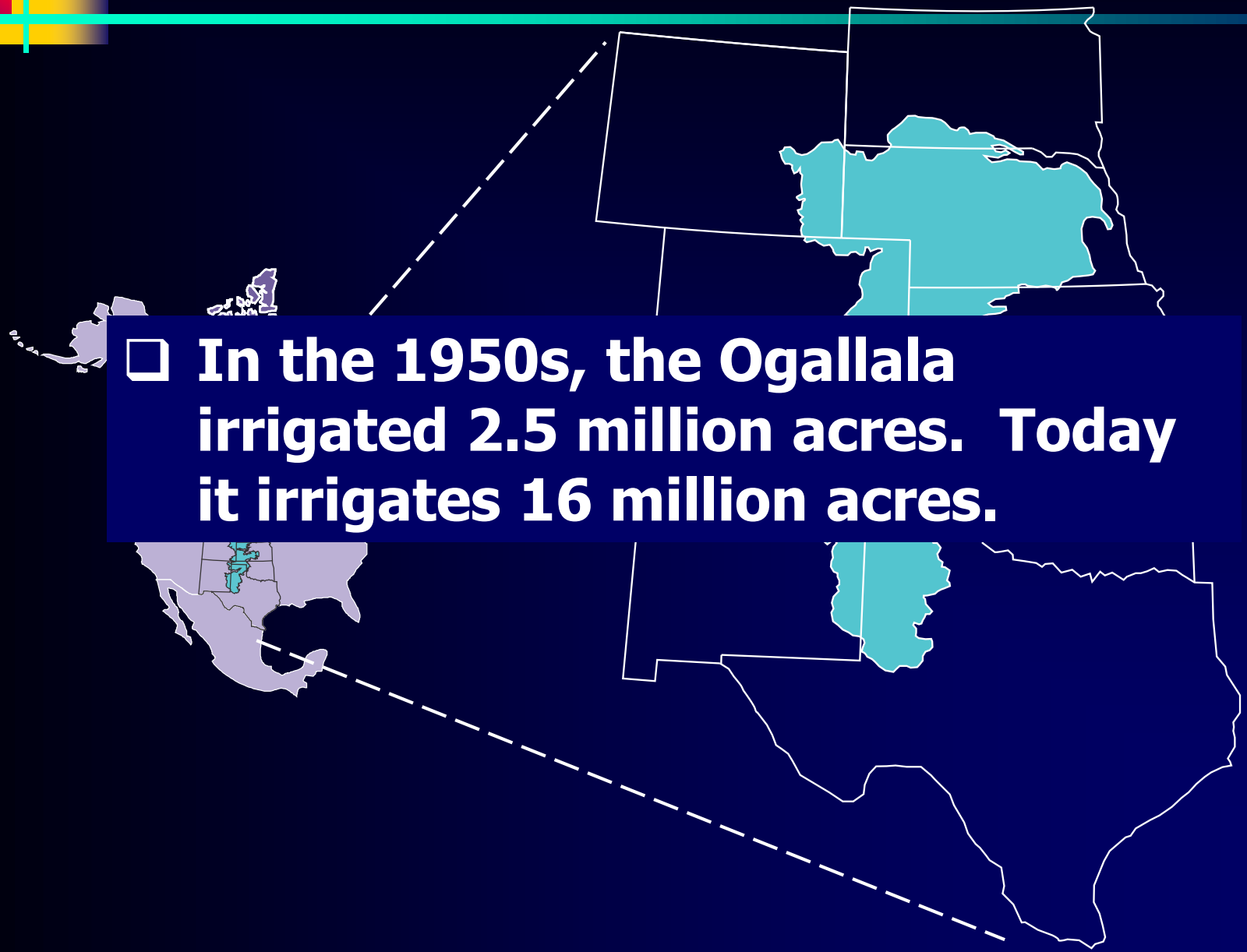
Fossil Groundwater Use for Food Production

*The Ogallala Aquifer**

- It underlies 174,000 square miles.
  - Nebraska – 64,400 sq. miles
  - Texas – 36,080 sq. miles
  - New Mexico - <10,000 sq. miles
  - Oklahoma - <10,000 sq. miles
  - South Dakota - <10,000 sq. miles
  - Wyoming - <10,000 sq. miles
- The aquifer contains 3.3 billion acre-feet of water.
- Alberta's total annual water supply from all rivers is about 0.1 billion acre-feet.

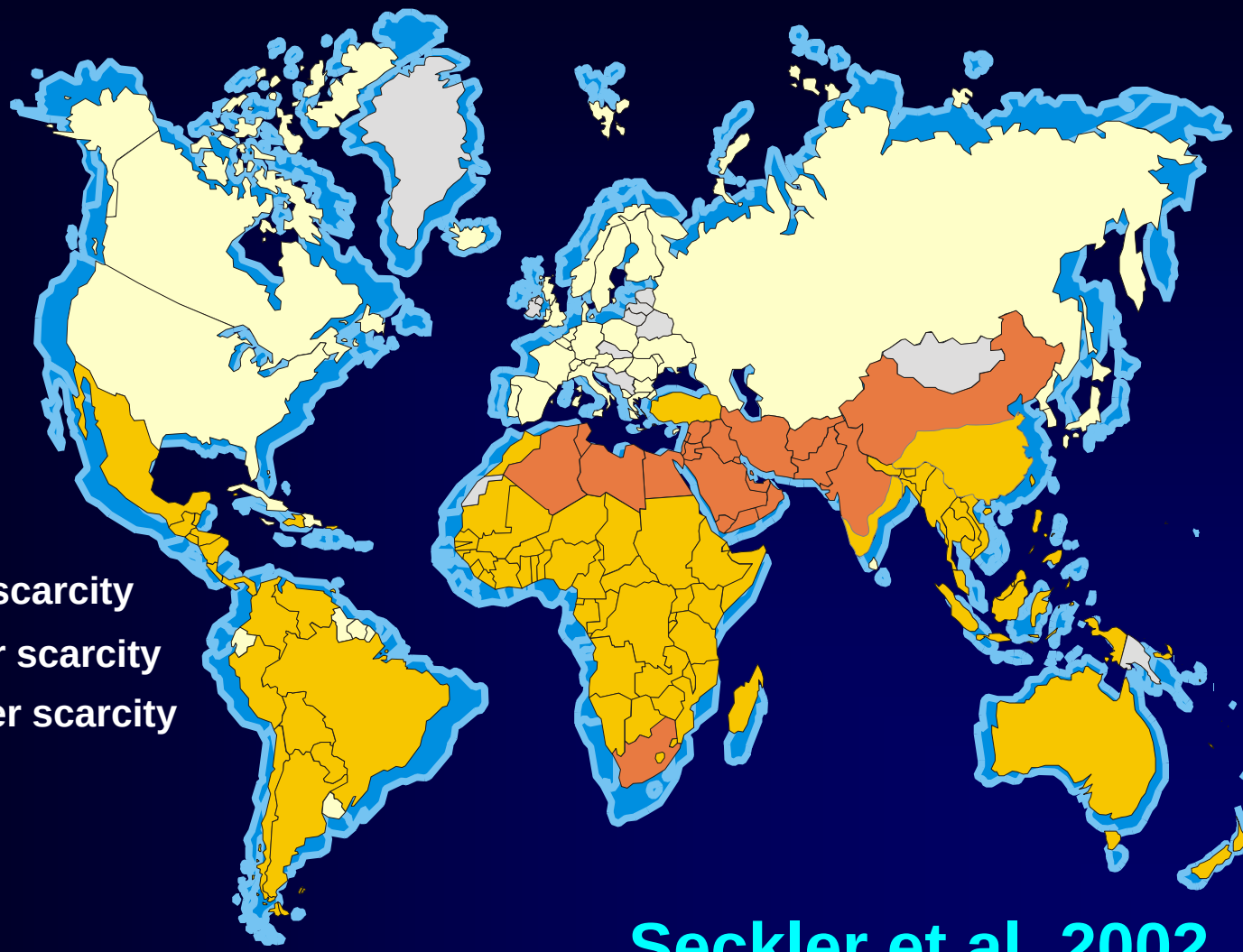
*** M. V. Guru – the Ogallala Aquifer – July, 2000 (Kerr Centre for Sustainable Agriculture)**

The Ogallala Aquifer



- In the 1950s, the Ogallala irrigated 2.5 million acres. Today it irrigates 16 million acres.

Projected Water Scarcity in 2025



- Physical water scarcity
- Economic water scarcity
- Little or no water scarcity

Seckler et al, 2002

Global Water Use

- In 1995, the human population withdrew 3,906 km^3 of water annually (31% of the readily available water).
- By 2025, withdrawals will increase by 22% to 4,772 km^3 (38% of readily available water).
- Withdrawals in developing countries will increase by 27%, while developed countries will increase by 11%.

Global Water Outlook to 2025
Rosegrant et al 2002

Future World Food Requirements

- World food requirements could double in the next 40 years.
  - Population growth.
  - Per capita food consumption will increase.
  - Significant changes in diet from carbs to protein.

Health implications?

Implications to Cereal Production

- 1 kg of chicken meat requires:
  - 3 kg of grain equivalents;
- 1 kg of pork meat requires:
  - 5 kg of grain equivalents
- 1 kg of beef requires:
  - 8 kg of grain equivalents;

Irrigated Food Production

- Irrigation makes up about 17% of the total arable land base.
- About 40% of the world's food, and 60% of cereal production is from irrigated lands.
- Significant increases in production on rainfed lands are difficult – genetic engineering has not yet developed high yielding, drought-resistant varieties.
- It is estimated that up to 80% of future food requirements will be met by irrigation.

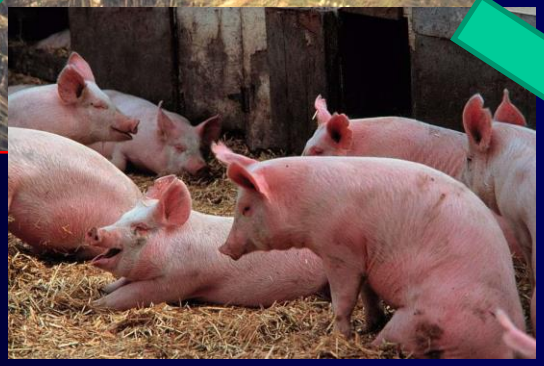
World Food Production

In the future, water rich countries like Canada and the U.S. will be increasingly called upon to supply the additional food requirements for much of the world.

Planning For Food

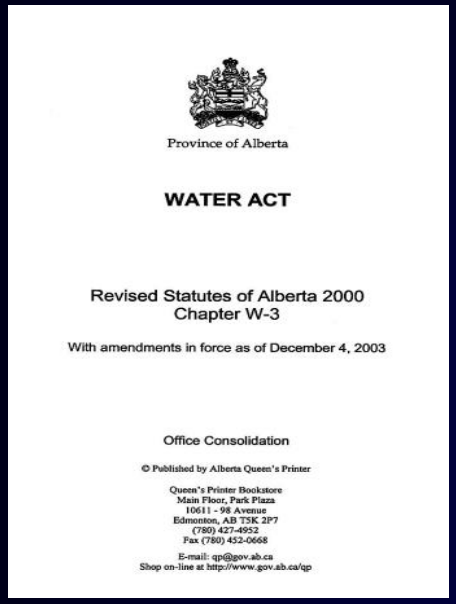
- Food-poor but cash-rich countries are buying up agricultural rights in developing countries and "bread basket" countries.
  - South Korea – 99 year lease on 3.2 million acres in Madagascar.
  - China – 100,000 acres in Australia.
  - Japan – 500,000 acres in the U.S.

Water, agriculture (environment) and food (human health) have been closely linked throughout history.



Water Management

Policies in Alberta



Province of Alberta

WATER ACT

Revised Statutes of Alberta 2000
Chapter W-3

With amendments in force as of December 4, 2003

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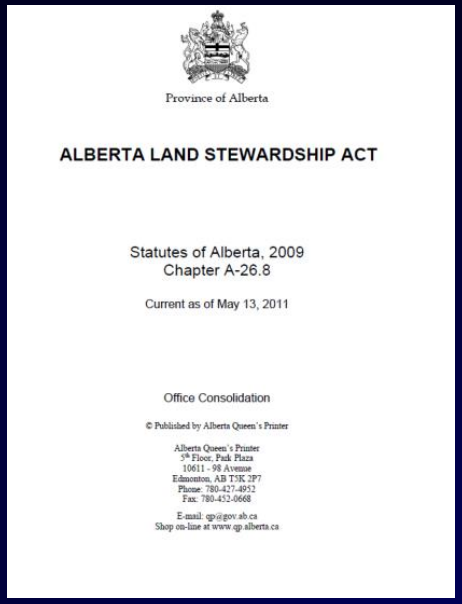

Province of Alberta

ALBERTA LAND STEWARDSHIP ACT

Statutes of Alberta, 2009
Chapter A-26.8

Current as of May 13, 2011

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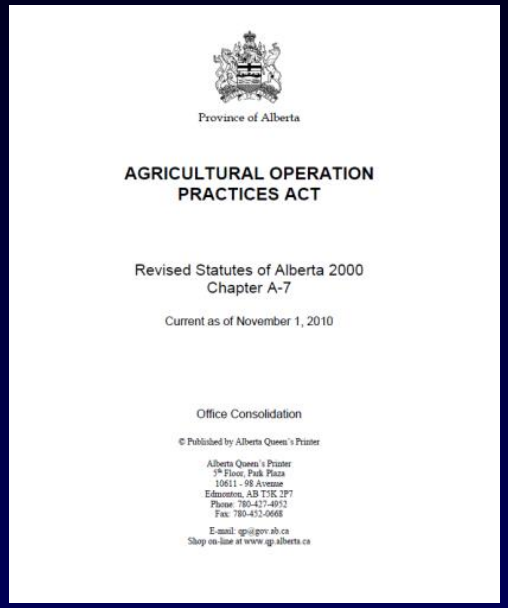

Province of Alberta

AGRICULTURAL OPERATION PRACTICES ACT

Revised Statutes of Alberta 2000
Chapter A-7

Current as of November 1, 2010

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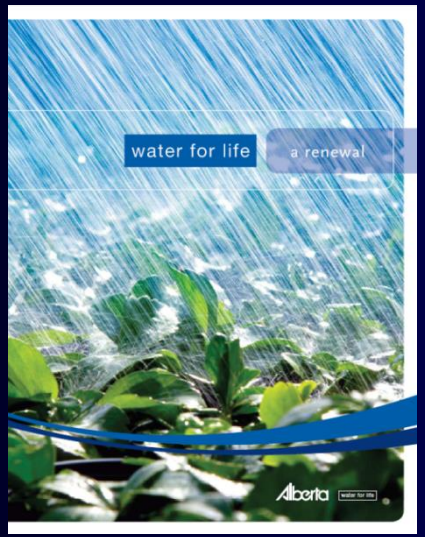
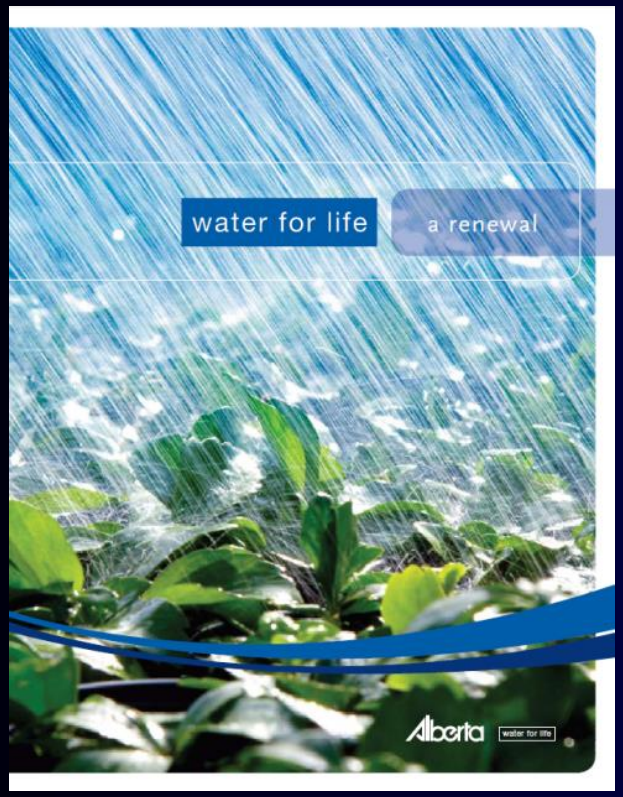


Alberta's Water For Life Strategy



Since 2003:

- ❑ Safe, secure drinking water
- ❑ Healthy aquatic ecosystems
- ❑ Reliable, quality water supplies for a sustainable economy

Three pillars (SEE): Social, Environmental, Economic

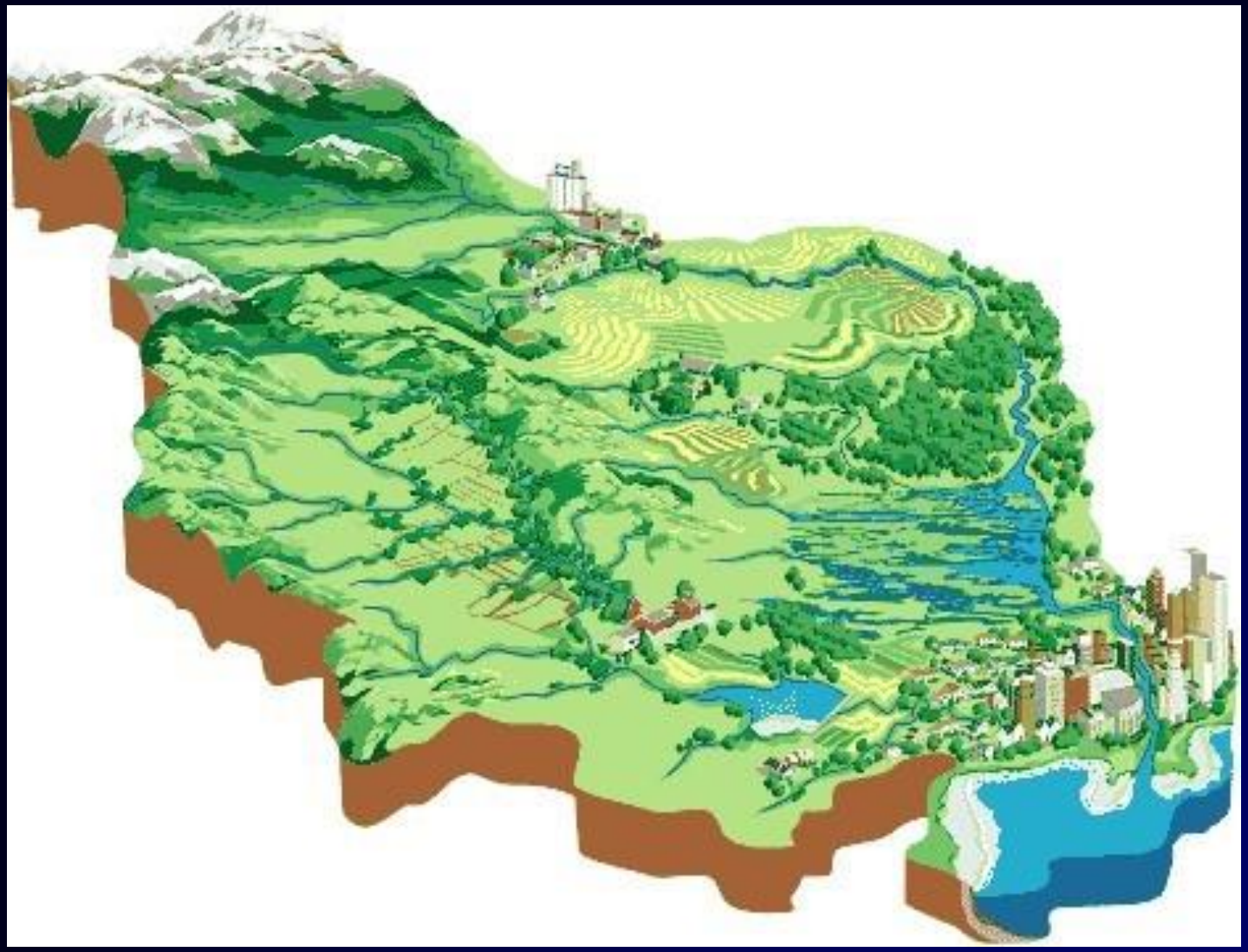
Watersheds

The area of land where all of the water under it or water that drains off it goes to the same place.

"that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of the community" John Wesley Powell

Also called: *drainage basins* or *catchment basins*.

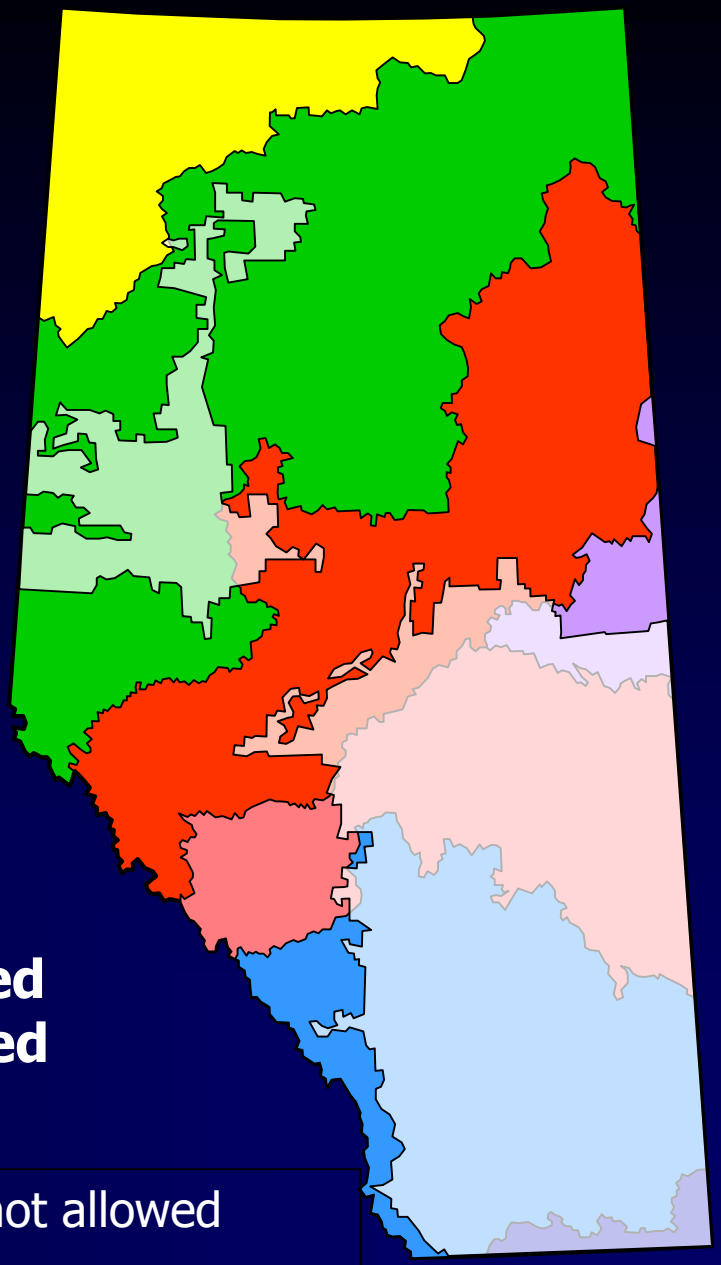
Watershed management



Seven major watersheds of Alberta

Agricultural areas
21.1 million ha
32% of Alberta's land base

Surface water cover
1.7 million ha
2.5% of Alberta's land base

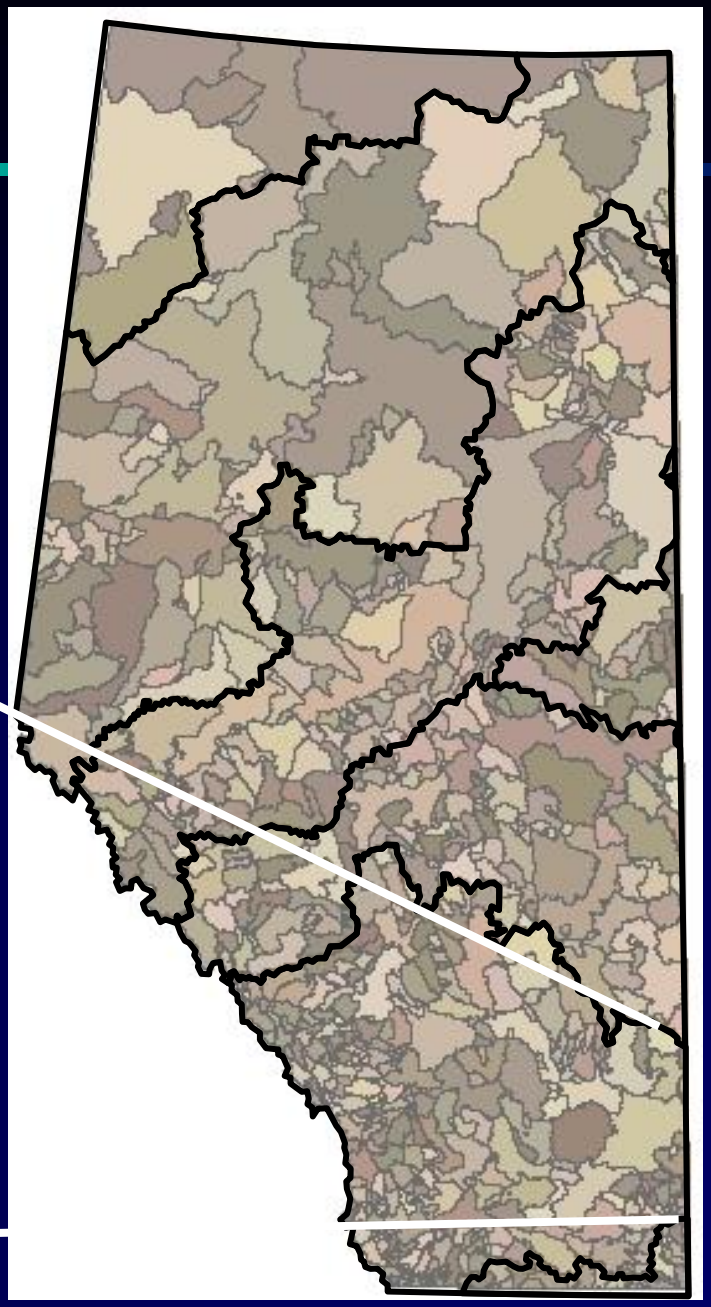


- **Hay River Watershed**
- **Peace River Watershed**
- **Athabasca River Watershed**
- **Beaver River Watershed**
- **North Saskatchewan River Watershed**
- **South Saskatchewan River Watershed**
- **Milk River Watershed**

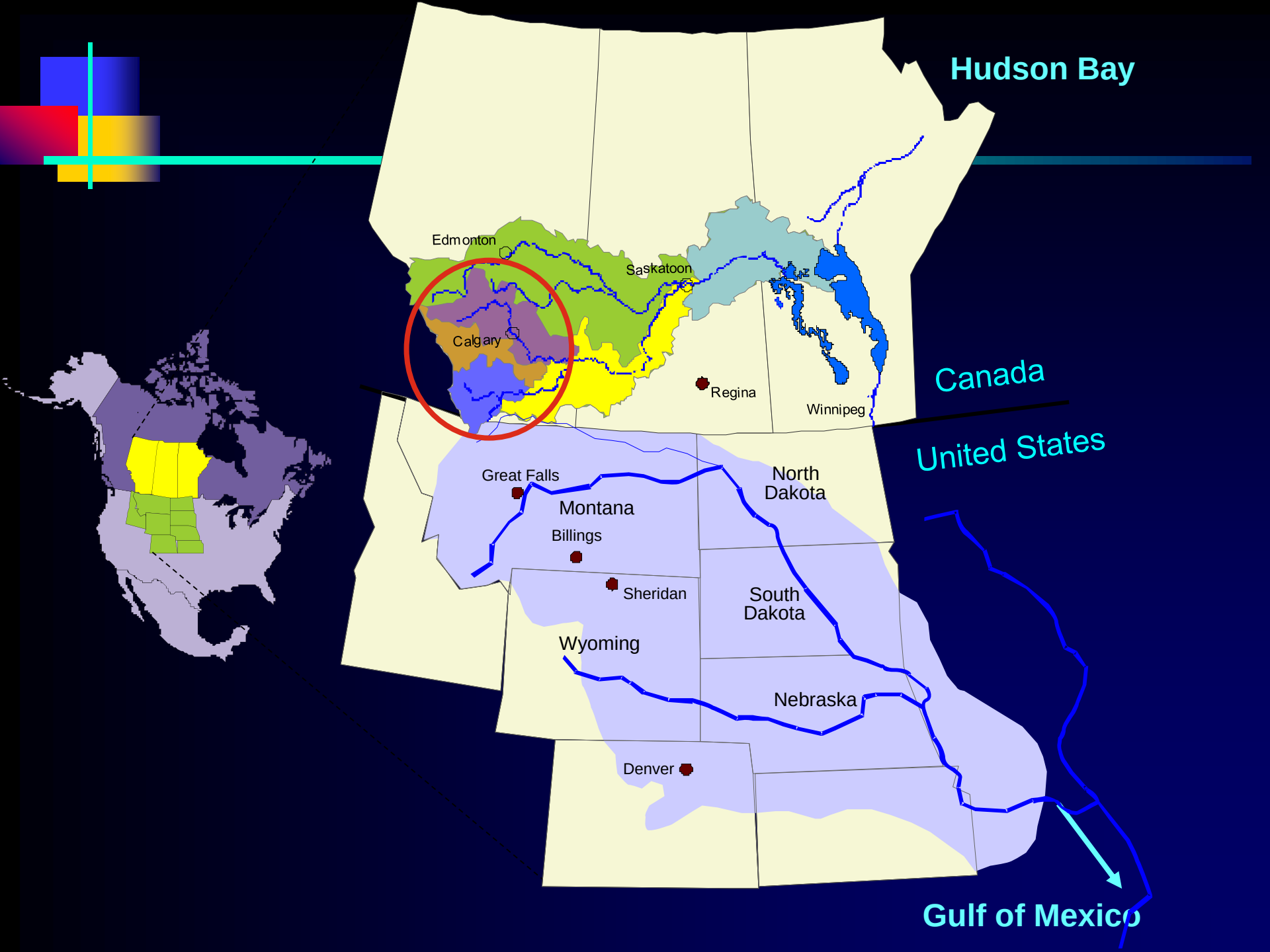
- Transfer of water between these watersheds is not allowed without special provincial legislation.
- Bulk export of water is also not allowed.

Sub-watersheds

South Saskatchewan River Basin

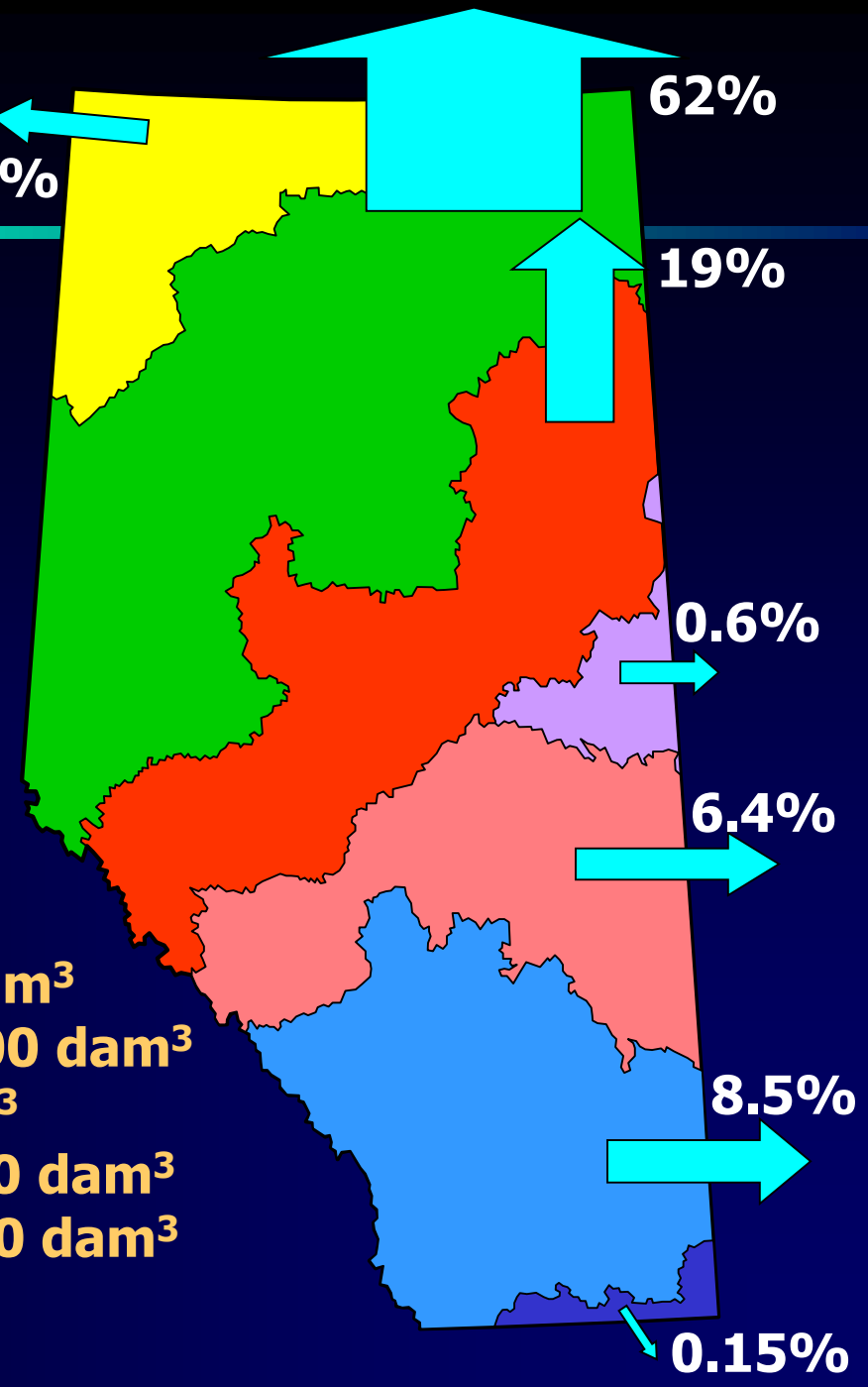


Watersheds are not politically bound


Hudson Bay
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
Canada
United States
Great Falls
Montana
Billings
North Dakota
Sheridan
South Dakota
Wyoming
Nebraska
Denver
Gulf of Mexico

CANADA
DRAINAGE BASINS
ARCTIC
ATLANTIC
GOLF OF MEXICO

Water flows

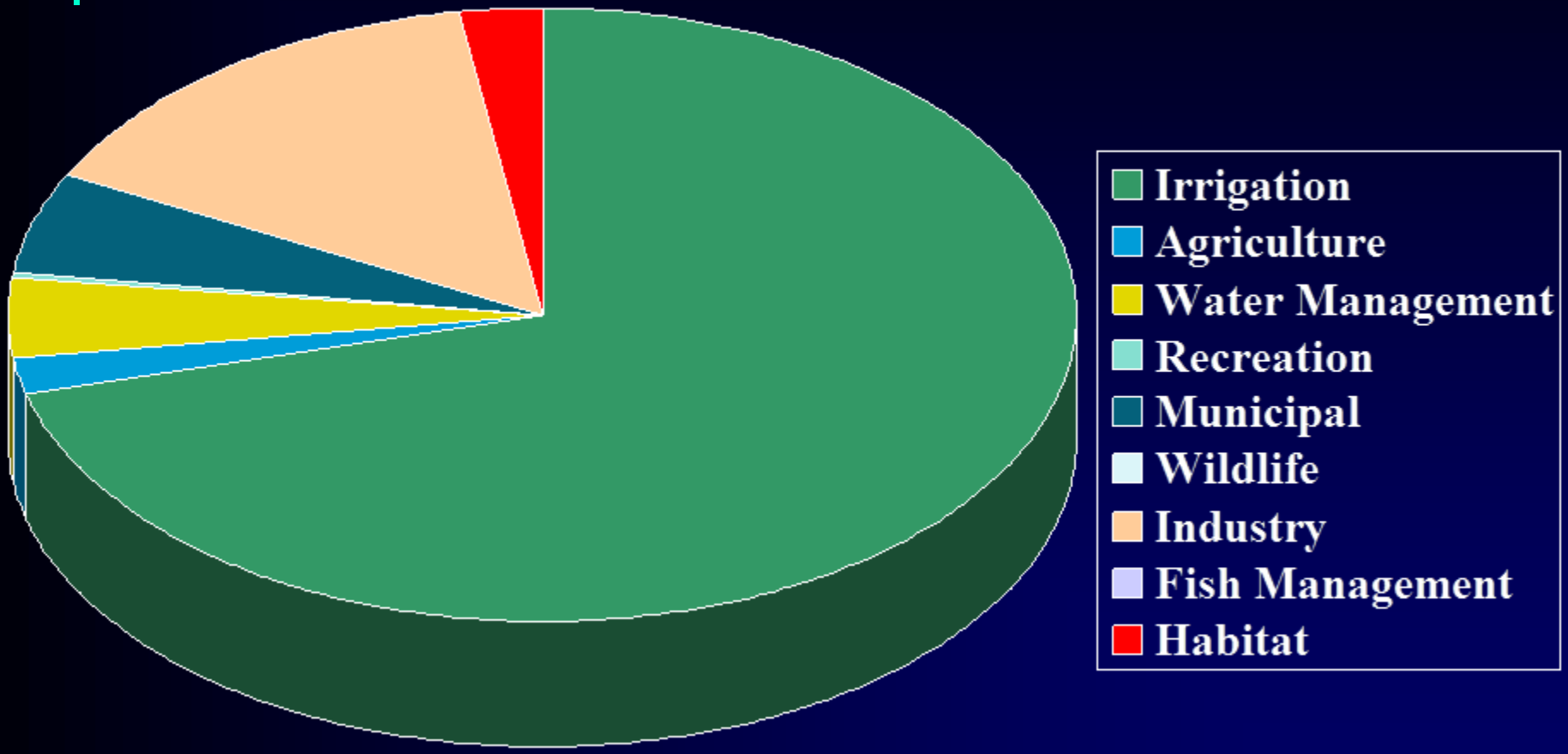


- Hay River 3,630,000 dam^3
- Peace River 68,200,000 dam^3
- Athabasca River 20,860,000 dam^3
- Beaver River 653,000 dam^3
- North Sask River 7,000,000 dam^3
- South Sask River 9,280,000 dam^3
- Milk River 167,000 dam^3

Annual River Discharges and Use

- Most of the water flows out of the province unused.
- Total volume withdrawn – 3.8 million acre-feet (3.6%).
- Total volume consumed – 2.1 million acre-feet (2%).
- Total outflow from Alberta's rivers is about 105 million acre-feet per year.

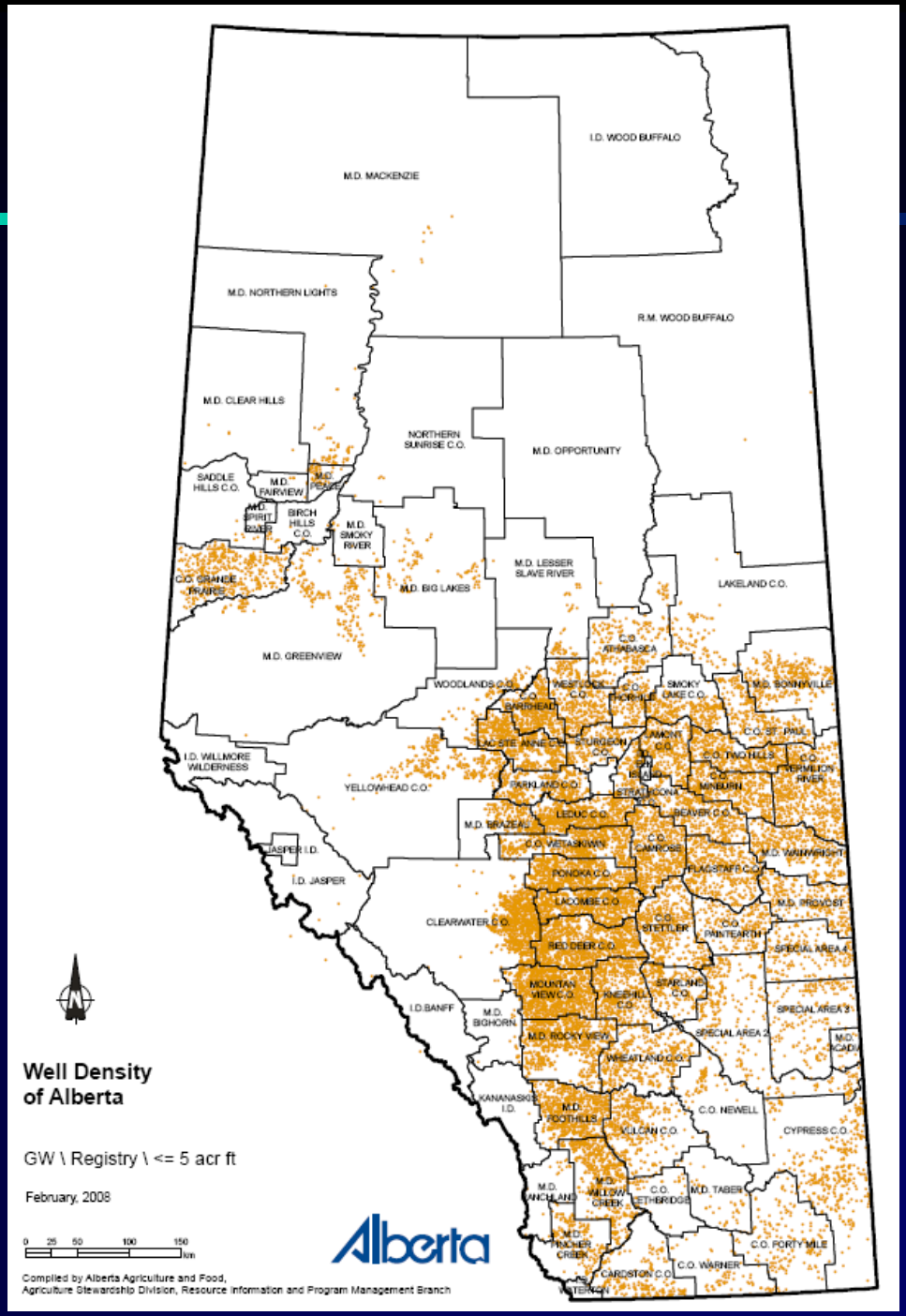
Consumed water in Alberta



- 97.5% of consumptive use is from surface water.
- 2.5% of consumptive use is from groundwater.
  - Currently 500,000 domestic wells in Alberta.
  - About 7,000 new wells are added each year.

Groundwater Well Distribution

We understand much less about our groundwater resources than our surface water resources.



Alberta's Water Supply

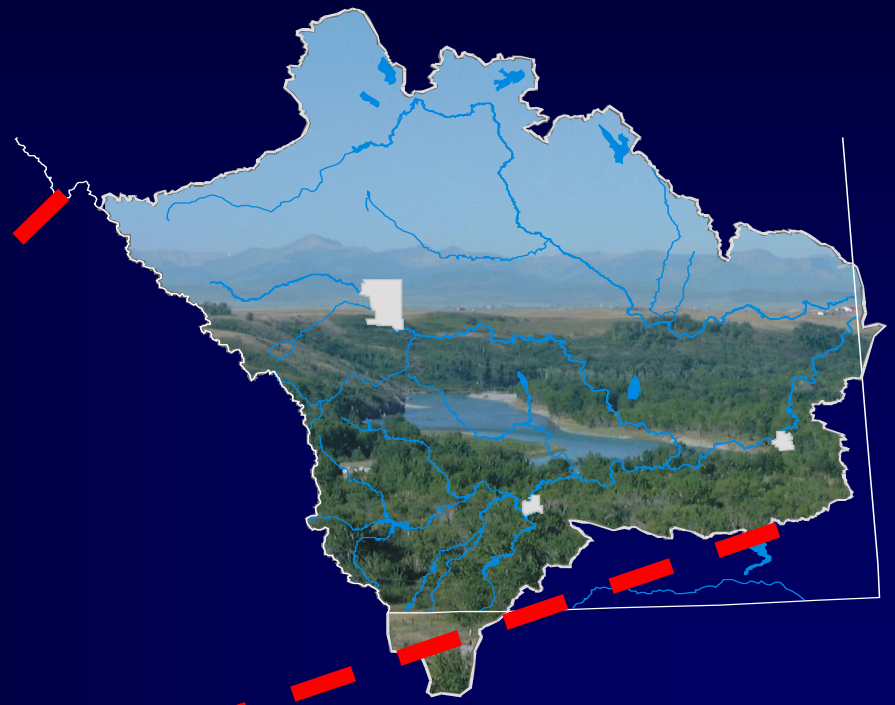
- Alberta has an abundant supply of water.
- However, water supplies aren't always in the right place, and at the right time.

The people are not where the water is

Only 10% of the renewable water supply serves more than 90% of the province's population.

Irrigation is not where the water is

- Alberta has 60% of the irrigated land in Canada and it is located in the SSRB.
- Irrigation occurs in semi-arid regions.



South Saskatchewan River Basin (SSRB)

SSRB is closed to new water licenses

- During years of drought, the water requirements in the SSRB may exceed the amount of available water.
- There has been a moratorium on water licenses since 2006.
- The drought in 2002 set a precedent of water sharing between license holders.
- Priorities for irrigation water use: people and animals, industry, then crops.
- Climate change may result in increased weather extremes (flood and drought).

What is the source of water in the SSRB?

- Snowpack from the Rocky Mountains is the source of water to rivers within the SSRB.
- The provincial government monitors snowpack to forecast river supply.
- Years of low snow may result in drought.

http://environment.alberta.ca/forecasting/WaterSupply/

Mountain snowpack
Snow accumulations measured in the mountains as of February 1, 2015:
Oldman River basin: ranging from 44 to 89% of normal
Bow River basin: ranging from 63 to 112% of normal
Red Deer basin: ranging from 93 to 123% of normal

SSRB Water Storage Reservoirs

Are critical to an assured water supply during the summer.

On-stream Reservoirs = 5
Off-stream Reservoirs = 50

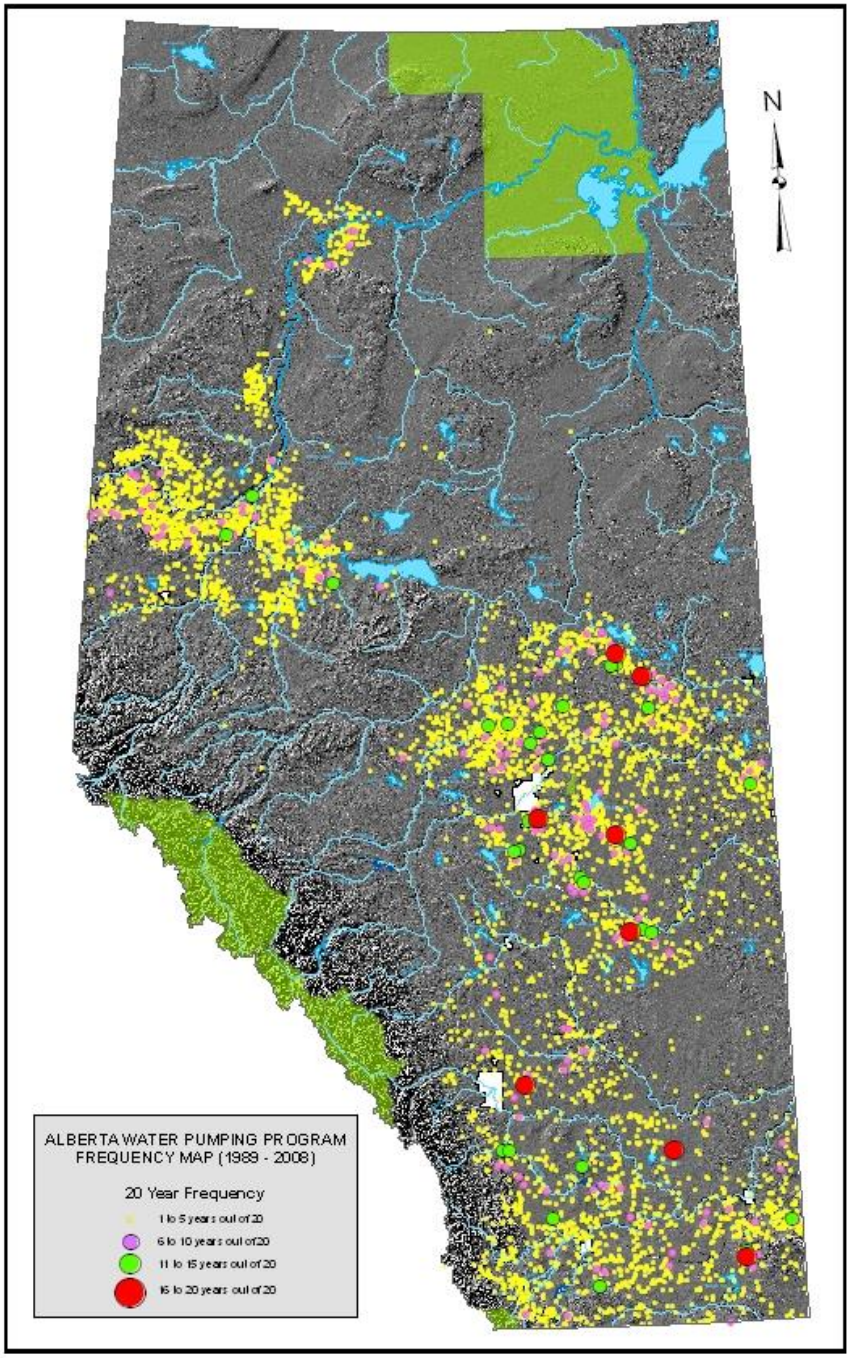
Total Storage ~ 2.5 M ac-ft.

Safe, reliable water

About 500,000 Albertans depend on un-regulated drinking water.

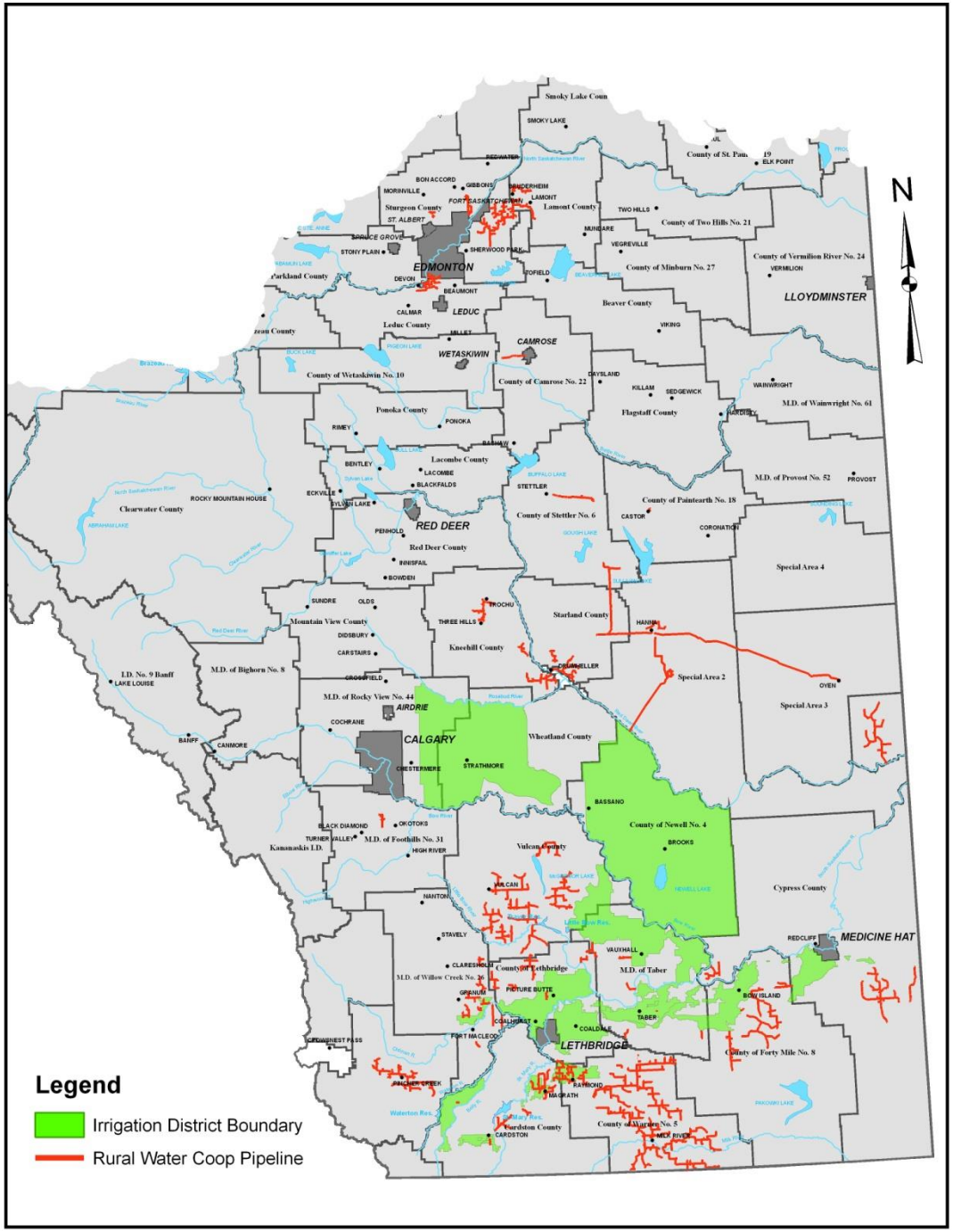
- ❑ Groundwater wells
- ❑ Streams and rivers
- ❑ Farm dugouts

Many areas of the province are chronically short of water.

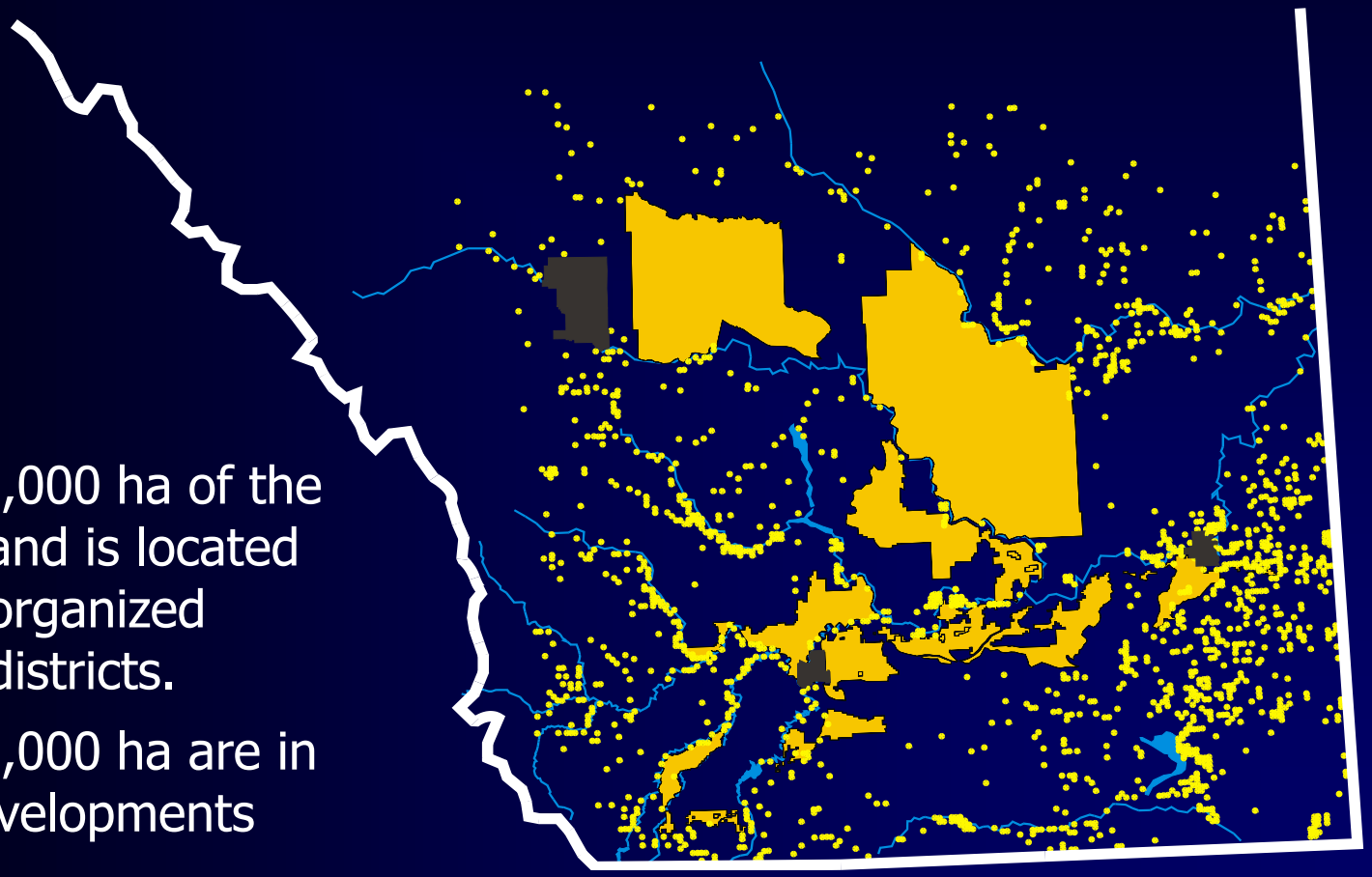


Rural Water Supply

- Permanent regional water supply pipelines would provide an assured supply of water to producers and rural residents in water-short areas.
- This is a "water to the people" approach of water management.



Irrigation in Alberta



- About 520,000 ha of the irrigated land is located in the 13 organized irrigation districts.
- About 120,000 ha are in private developments

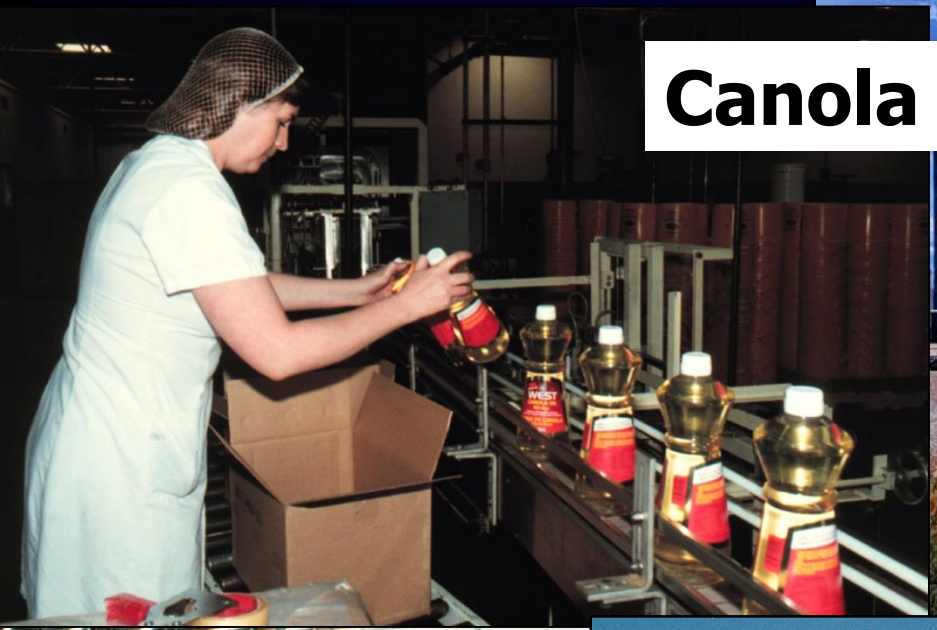
Economic Impact

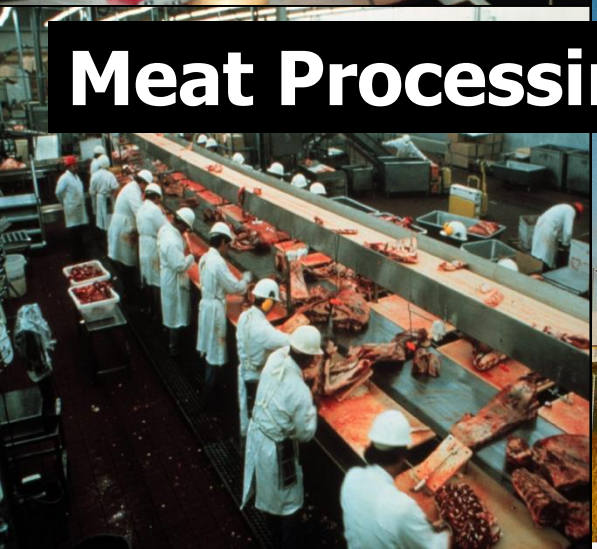
- Irrigation represents <5% of Alberta's arable agriculture land base.
- Irrigation accounts for 18-20% of the provincial agricultural gross domestic product.
- More than 30% of Alberta's food processing returns are associated with irrigation.
- More than 50 different crops are produced under irrigation.

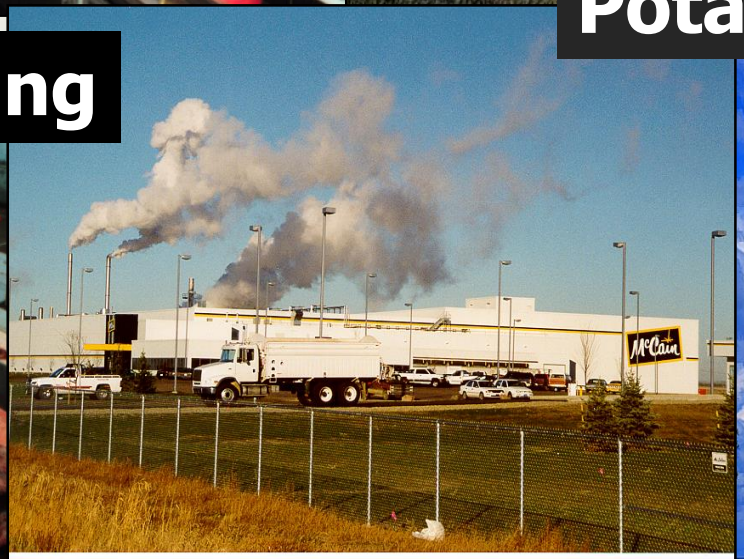
Irrigation water users

- Irrigation infrastructure in the SSRB provides water for:
  - 50 towns and villages;
  - Processing plants;
  - Intensive livestock operations;
  - Recreation facilities; and
  - Wildlife habitat (32,000 ha).

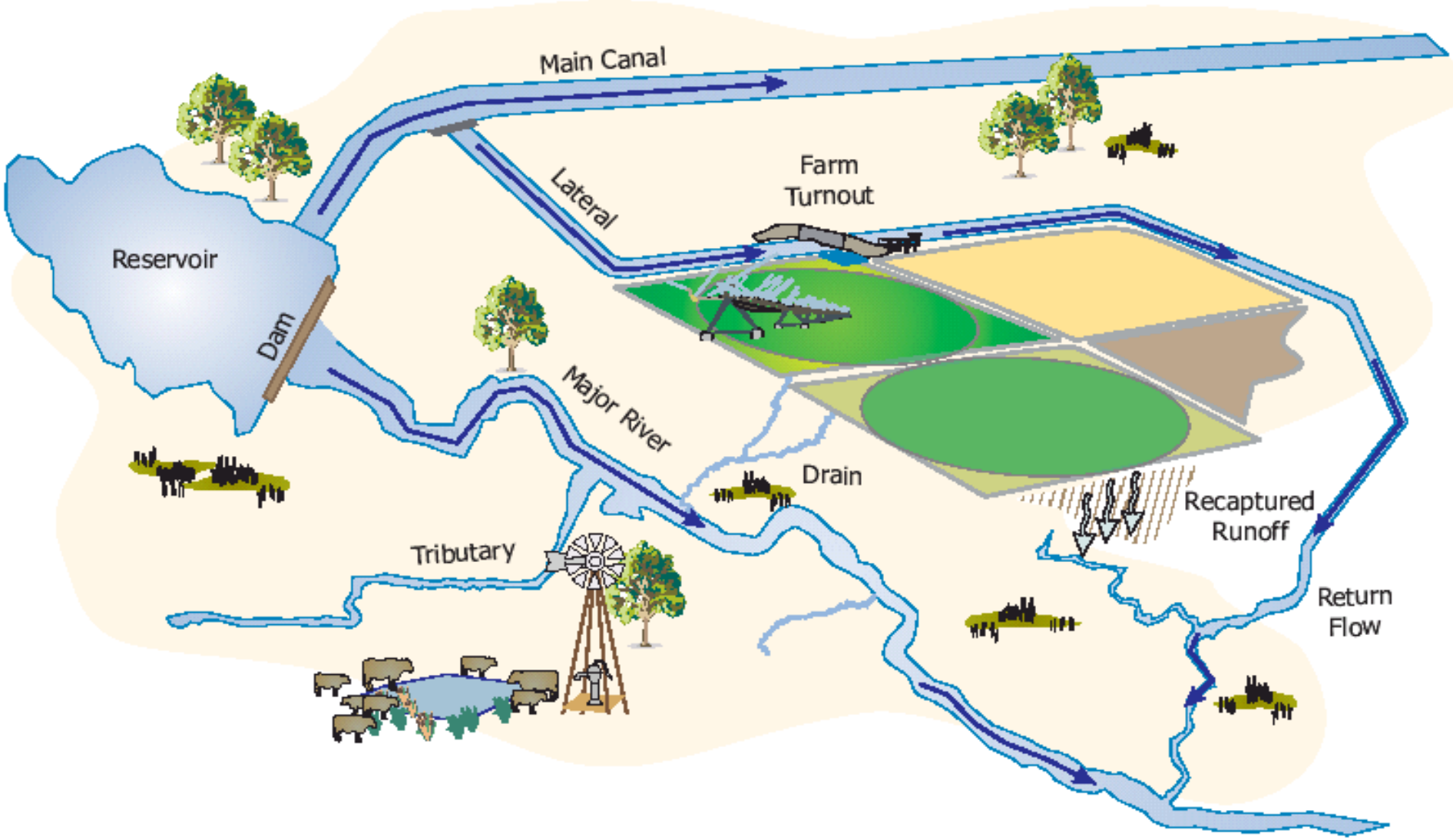
Food Processing Industries







Irrigation System



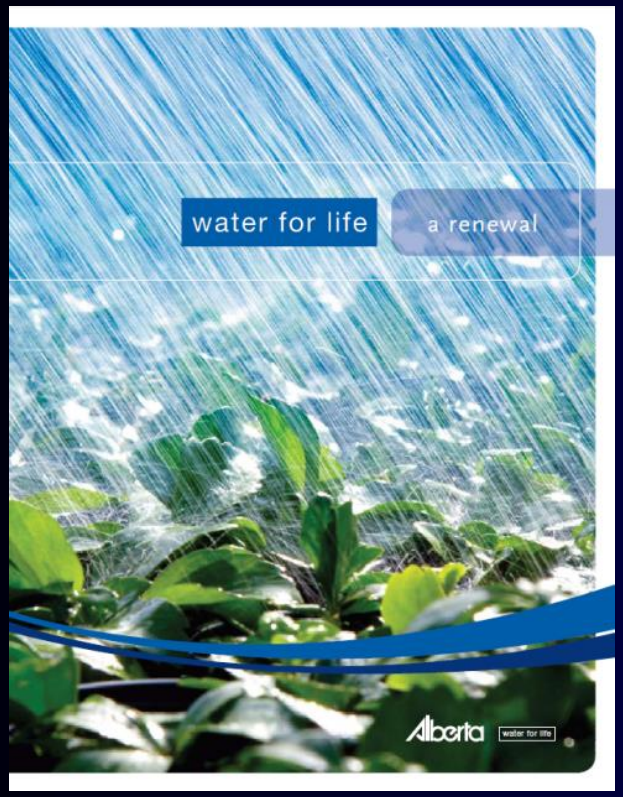
Alberta's Irrigation Infrastructure

Conveyance Works >8000 km

- 53% Open channel

- 47% Buried pipeline

Alberta's Water For Life Strategy



- Reliable, quality water supplies for a sustainable economy
  - Water conservation, efficiency and production

"More crop for less drop"

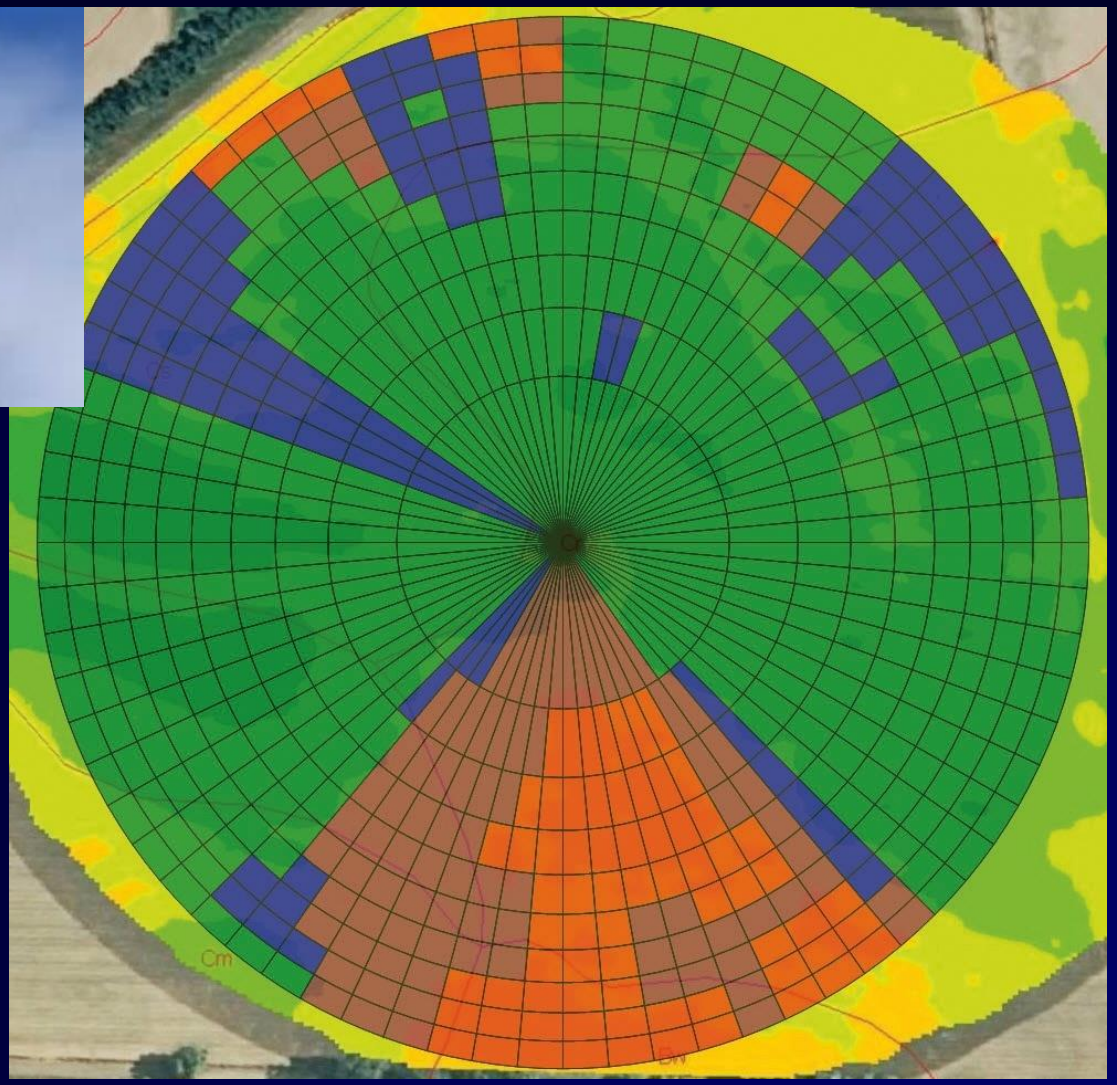
Efficiency Gains

- From 1999 – 2008, improvements in irrigation conveyance infrastructure resulted in annual water savings of about:
  - 47 million m^3 from canal seepage; and
  - 2.4 million m^3 from canal evaporation.
    - Equal to ~20,000 Olympic-size swimming pools.

On-Farm Irrigation Efficiency

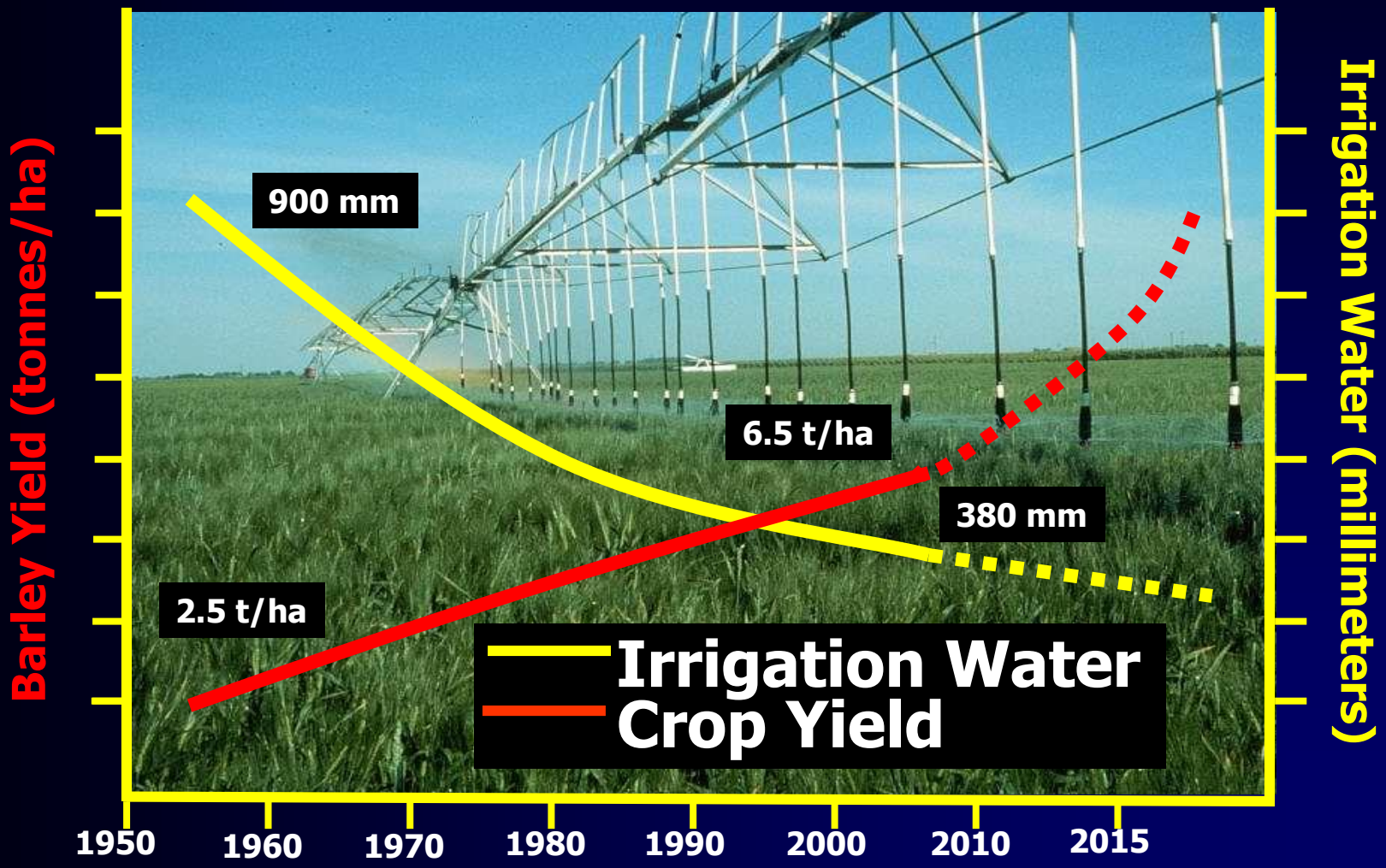
Low pressure, drop tube pivot

Variable Rate Irrigation (VRI)



- Combining drones with "smart" irrigation technology.
- This improves irrigation efficiency and crop quality.

More crop for less drop



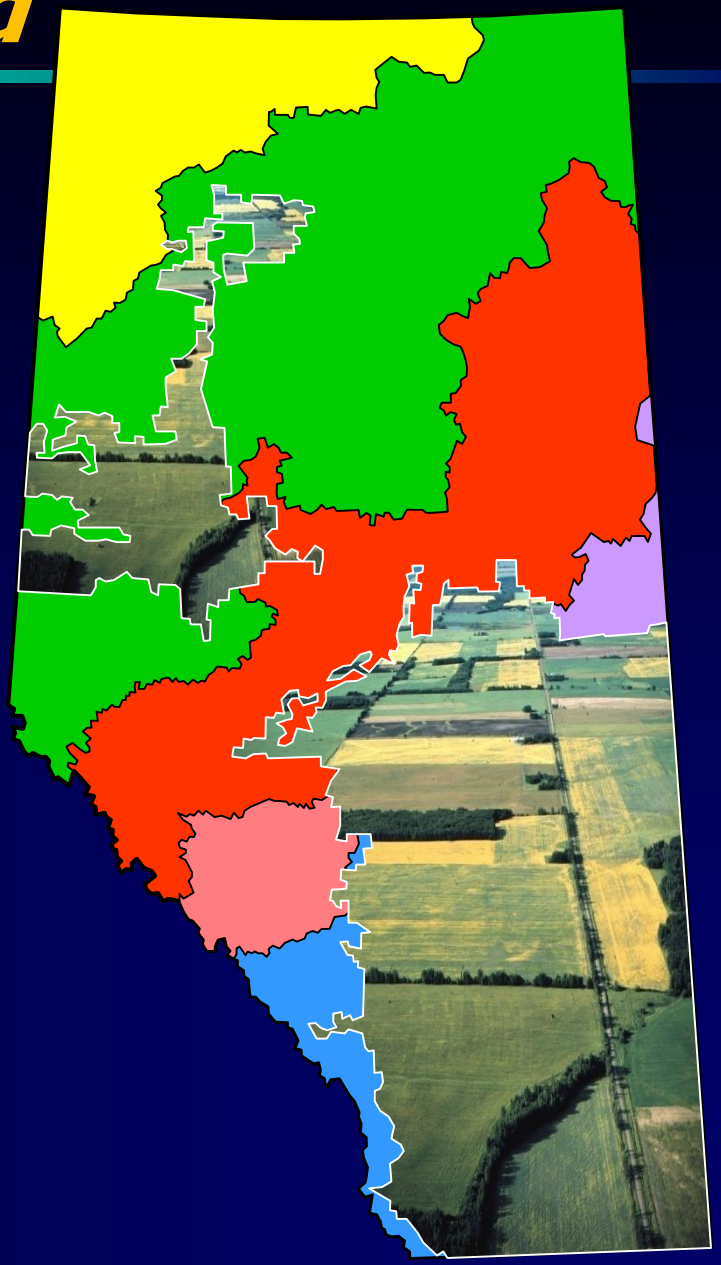
Production Potential

- Alberta has significant room to increase crop and livestock production in response to world markets.
- The agriculture industry needs access to adequate, good quality water to meet the potential of a growing world marketplace.
- Agriculture must complete with other water users.

Climate Change and Crop Water Demand

- It is expected that agriculture will need more water with climate change.
  - A 2° C increase will require 28% more water for alfalfa.
  - A 4° C increase in temperature will require 63% more water.

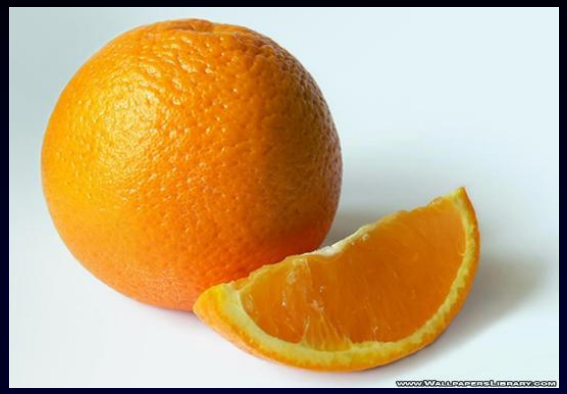
- An additional 425,000 acre-feet of irrigation water will be required within the irrigation districts (~20% more water than is currently diverted).



Harms – ARD, 2010

Watershed management - Finding the balance

Water quality



Oranges
$0.99 per 100 g
China

Grapes
$1.99 per 100 g
Mexico

Blueberries Sale!
$1.99 per 170 g package
California

Health Canada and Public Health Agency of Canada

Canada has one of the highest per capita consumption of fruits and vegetables in the world.

- **6 to 7 servings per day (USA 4)**

As global markets expand, so does the potential of foodborne illness. In Canada:

- **86% fruit and 41% of vegetables imported**
- **food safety protocols in some countries unknown**

Many outbreaks the result of postharvest contamination.

- **transport, sorting, storage, packing, cutting**

Pathogen Produce Recalls in Canada

Canadian Food Inspection Agency:

April 29, 2011
Tomatoes
Salmonella
Grown in Florida

Aug 8, 2011
Strawberries
E. coli O157
Grown in US

July 14, 2010
Pre-packaged salad kits
E. coli O157
Grown in Florida

Aug 15, 2010
Green onions
Salmonella
Outbreak in Ontario

From 2001 to 2009, there were 27 produce outbreaks in Canada (1549 illnesses).

- **26% leafy greens/herbs**
- **11% sprouts**

Estimated 11 million episodes of foodborne illness annually.

- **For every 1 reported, 300+ go unreported**

The Media: 2012

CBC – Calgary, National Global Rutherford Calgary Herald

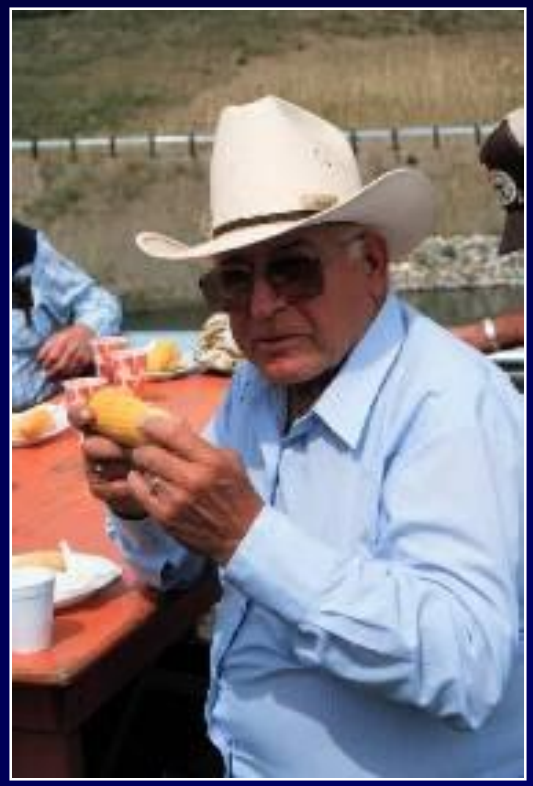
- Alberta Irrigation Water Brimming with E.coli
- Dangerous E.coli found in several rural Alberta areas
- E.coli O157 found throughout southern Alberta
- Is Canada's food safe?

Chris Bolton,

CEO Benchmark Labs

Water Quality ⟷ *Industry*

- Good water quality is important to ensure safe, quality food production.
  - Ability to produce food
  - Human health
  - Market access



What determines water quality?

NATURAL WATERSHED FEATURES

FLOWS

NON-POINT SOURCES

POINT SOURCES

ATMOSPHERIC DEPOSITION

INSTREAM "PROCESSES"

WATER QUALITY

How is water quality measured?

- Physical
- Chemical
- Biological

Physical water measurements

- temperature
- turbidity/clarity
- colour
- odour

Chemical water measurements

- Major Ions/Salts:
  - Cations: calcium (Ca), magnesium (Mg), sodium (Na), potassium (K)
  - Anions: bicarbonate/carbonate (HCO_3/CO_3), chloride (Cl), sulphate (SO_4), fluoride (F)
- pH: the acidic or basic nature of water
- Alkalinity: ability to neutralize acid
- Hardness: resistance to lather soap
- Nutrients:
  - Phosphorus
  - Nitrogen
- Dissolved Oxygen

Chemical water measurements

- Metals and Trace Elements:
  - Most abundant: iron (Fe), manganese (Mn), aluminum (Al), barium (Ba), strontium (Sr)
  - Most toxic: mercury (Hg), cadmium (Cd), lead (Pb)
  - Other common: arsenic (As), boron (B), chromium (Cr), cobalt (Co), copper (Cu), molybdenum (Mo), nickel (Ni), selenium (Se), silver (Ag), vanadium (V), zinc (Zn)
- Pesticides: herbicides, insecticides, fungicides
- Polycyclic aromatic hydrocarbons (PAHs)
- Chlorinated phenolic compounds
- Polychlorinated biphenyls (PCBs)
- Chlorinated dioxins and furans
- Pharmaceutical and personal care products

Biological water measurements

- Bacteria: total and fecal coliforms
- Protozoans: *Cryptosporidium, Giardia* (beaver fever)
- Cyanobacteria (blue-green algae): numerous species; can form dense blooms and release cyanotoxins
- Algae: Often measured by content of chlorophyll *a* (photosynthetic pigment)

Water Quality Guidelines

Canadian Water Quality Guidelines
Alberta Ambient Surface Water Quality Guidelines

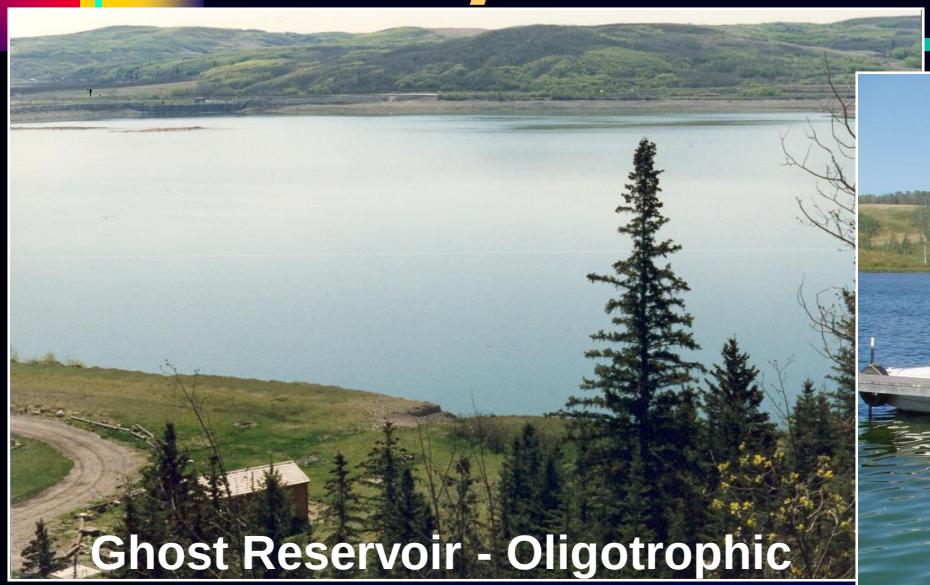
- target specific use
- no observable effects / most sensitive species is protected
- assume chronic exposure and safety factor of 10, 20, or 100X

Eutrophication

Is the natural process of lake aging, but can be accelerated by human activity.

- nutrient enrichment (P)
- extensive plant growth and decay
- reduced oxygen and cause fish kills
- health concerns: toxins, odours

Eutrophication in Alberta Waters



Dead zones in coastal waters

Anoxic water
(low oxygen)

Primary cause:
Agricultural fertilizer and sediment loss

Cirrhosis of the river.

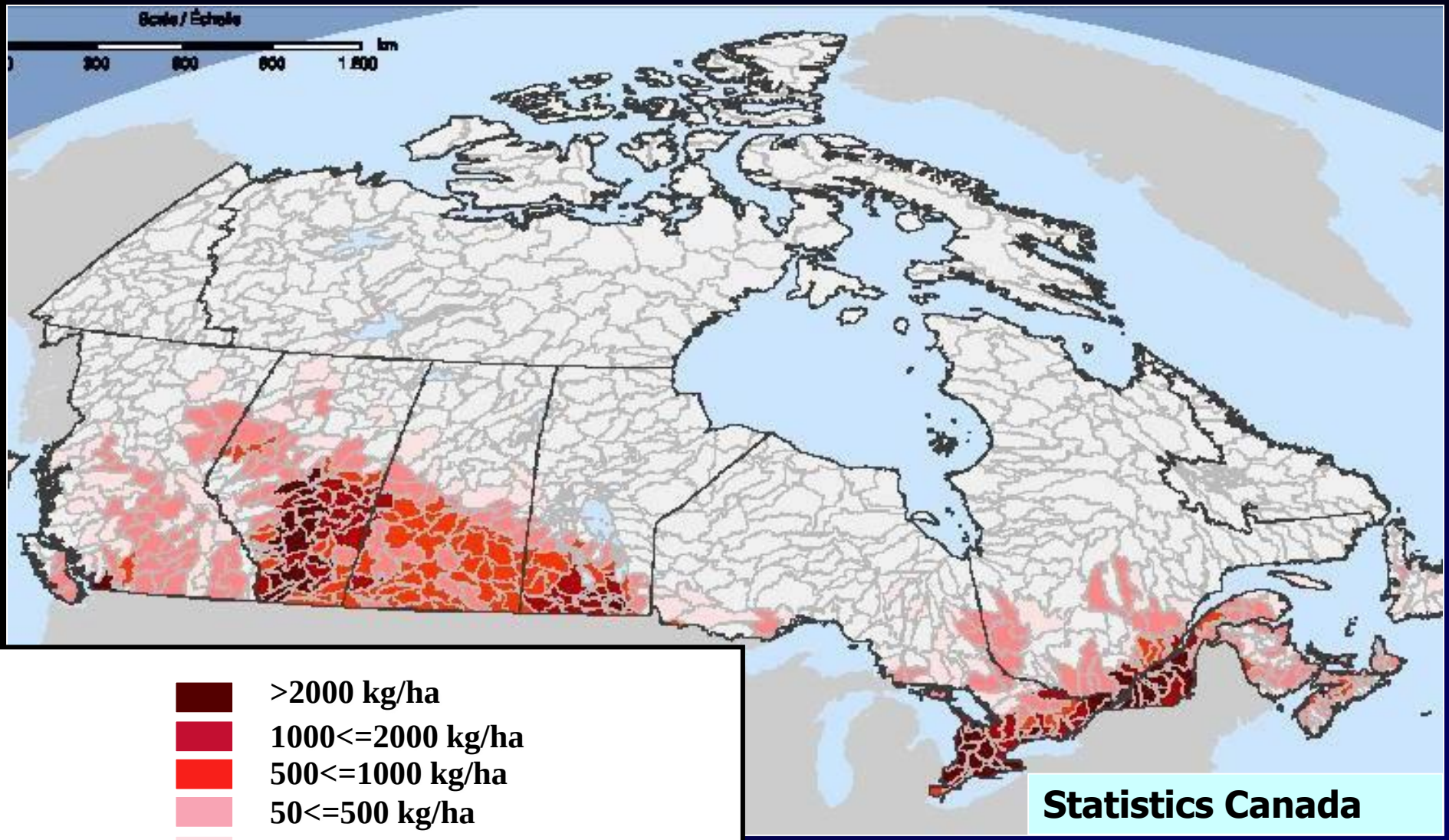
Agriculture and water quality

Agriculture is considered to be a leading cause of water quality problems throughout the world.

Agriculture's impact in Alberta

Livestock manure is considered to be a main agricultural contributor to water quality degradation.

Manure production in Canada, 1996



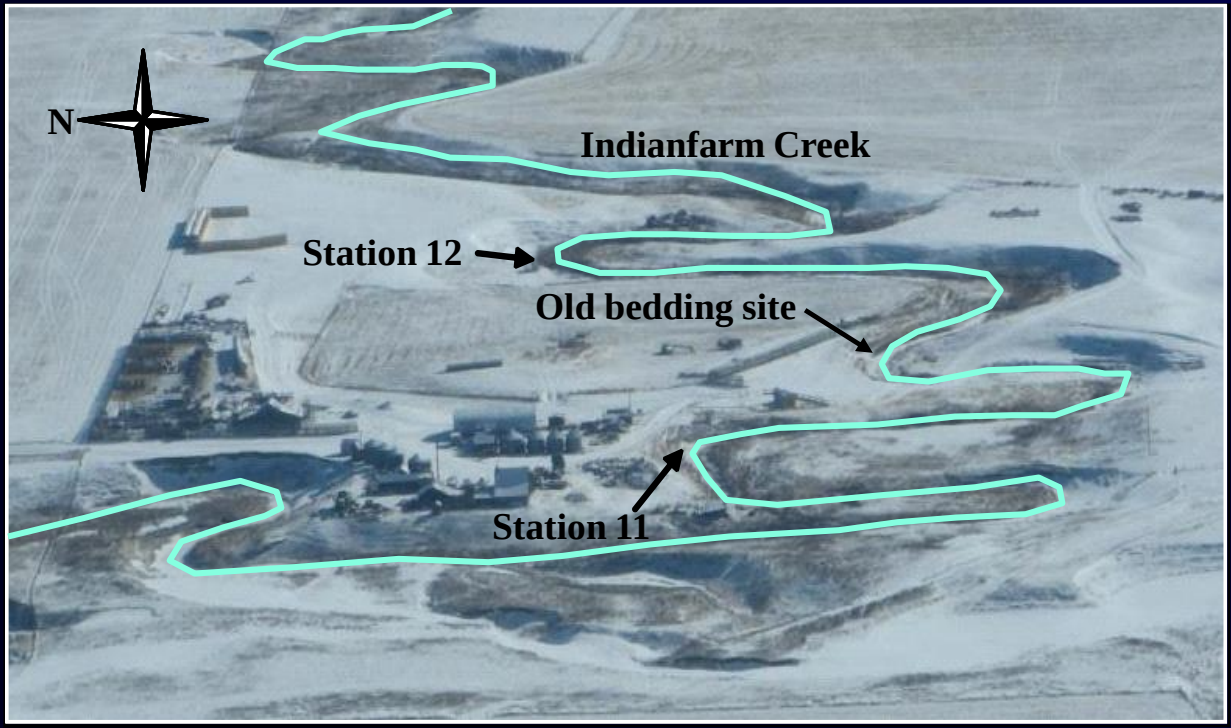
Nutrient losses

Beneficial Management Practices (BMPs)

Wintering Site (Indianfarm Creek Watershed)

- **Management unit: 6 quarter sections**
  - **Wintering site: 5 ha**

- **Grazing land adjacent to Indianfarm Creek**
  - **Supports 35 cow-calf pairs**



Wintering Site issues

- Location of winter bedding site
- Direct cattle access
- Degraded riparian areas
- Stream bank erosion
- Elevated TN, TP, and sediment concentrations

BMPs implemented

- Relocation of winter bedding site
- Livestock/grazing management plan
  - New fences
  - Off-stream watering system
  - Rotational grazing
- Bioengineering

Cost of BMPs:
$15,490
61 hours labour

Cost of bioengineering:
$12,960
21 hours labour

Wintering Site – key results

- **Implementation of the new wintering site and grazing plan worked well.**
- **Cattle spent about two-thirds less time in the riparian area.**
- **Riparian quality changed from unhealthy to healthy with problems (Cows and Fish assessment)**
- **Reduction in concentrations of:**

  Total N *
  Organic N *
  Total P
  Particulate P
  Sediment
  ***E. coli* ***

*** significantly reduced**

Bioengineering

Beneficial Management Practices (BMPs)

Millions have been spent on implementing thousands of BMPs for more than a decade.

- Environmental Farm Program (2003 to 2009)
  - 6,469 BMPs implemented
  - $30 M in federal government funds
- Growing Forward 1 (2009 to 2013)
  - 1657 BMPs implemented
  - $10 M in government funds
- Growing Froward 2 (as of June 2015)
  - 990 BMPs implemented
  - $10 M in government funds

Social license to operate

- Alberta's increasingly urban population is demanding the industry be more environmentally responsible.
- Industry includes: forestry, energy, and agriculture
- But….urban centers have a large impact on water quality too!

Water quality in Alberta

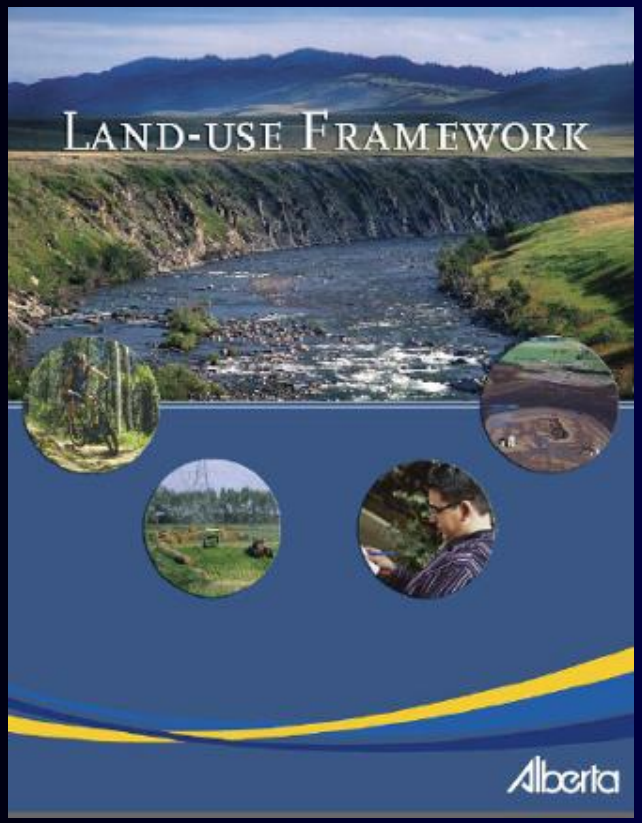
Alberta's water is not bad, but it is not pristine:

- Main stem rivers meet water quality guidelines; tributaries less compliant
- Alkaline
- Low metals concentrations
- Variable organic concentrations
- Naturally high in nutrients (nitrogen and phosphorus)

All water must be treated, prior to consumption!

Alberta's Land Use Framework

- Cumulative effects approach.
- Legislated water quality objectives are being implemented.
- All industries and water users will be expected to comply.



Challenges:

- Continued growth and development

Water quality in Alberta

Current Issues

- Beach closures: blue-green algae
- Arsenic in groundwater
- Water reuse
- Oil and Gas: tailings ponds, fracking

Emerging Issues

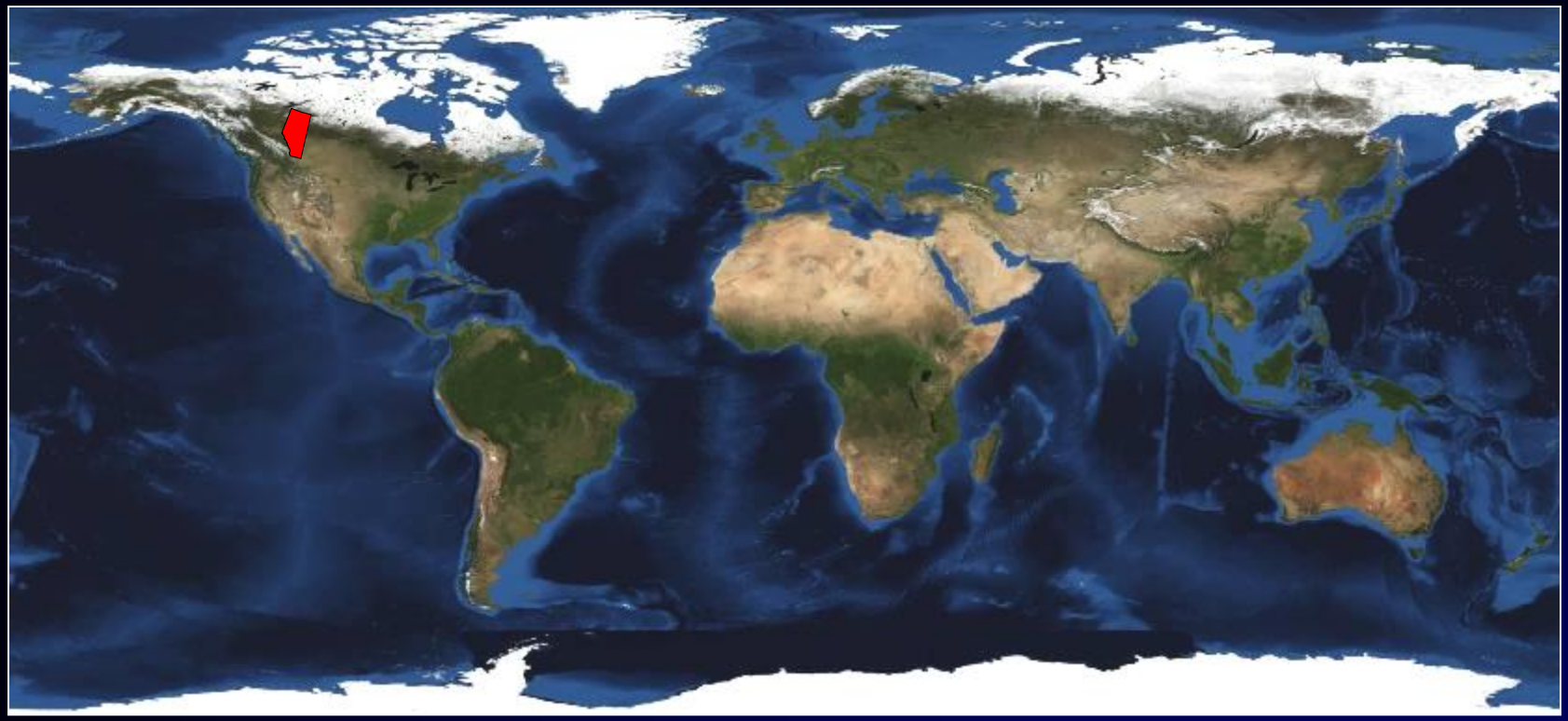
- Antimicrobials and microbeed impacts on human health
- Pharmaceuticals and personal care use products effects on fish

Albertans less likely to worry about water contamination: survey

By Karen Kleiss, Edmonton Journal February 17, 2015

Albertans are less likely to express concern about groundwater contamination from oil and gas development than are Canadians from other provinces, according to a new poll.
A survey of more than 2,000 Canadians found 52 per cent are concerned about the potential impact of hydraulic fracturing on drinking water, compared to 44 per cent of Albertans.
The practice, often called "fracking," involves injecting fluids into the ground at high pressure in an effort to crack the rock so that natural gas and oil can be extracted.

Alberta's potential



- ✓ An important competitive edge for Alberta is the world's acceptance that:
  - Our food is safe and of high quality
  - Our air, soil, and water are protected
- ✓ Challenge: how do we maintain or improve with continued growth?

Summary on Water and Health

- Earth has very little freshwater. It is a resource that is essential for life.
- Water supply, management and quality are important considerations. Watersheds do not respect political boundaries.
- The world is dependent on irrigated agriculture for food supply and it will become more so as the population grows and diets change.
- Alberta has abundant and relatively good quality water, but it is not always available where it is needed.
- The highest consumptive use of water in AB is irrigation agriculture.
- Current water and land policies in AB are guided by choices in the Social, Environmental and Economic pillars.
- Albertans will have to make critical choices on water use in the future. Those choices will affect our public health.

Ecological extremes that impact water - Floods and mussels

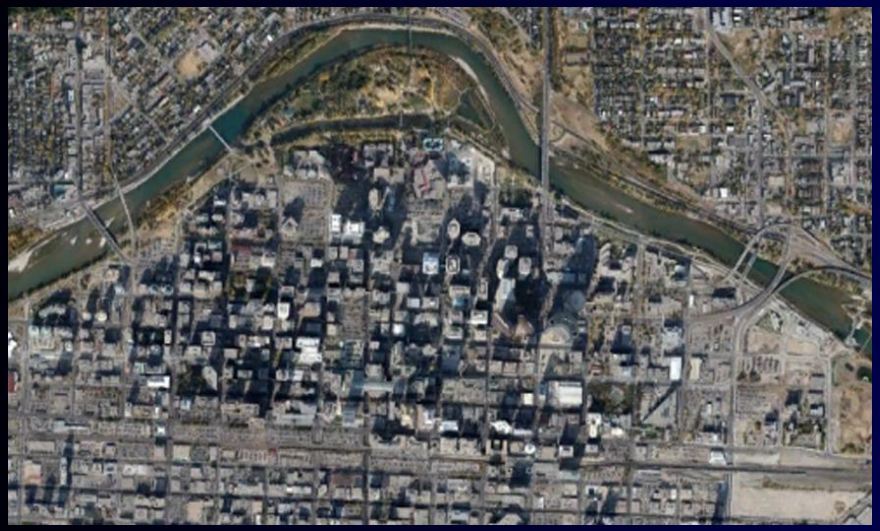
Alberta Flood Recovery Task Force 2013

Andre Corbould
Chief ADM

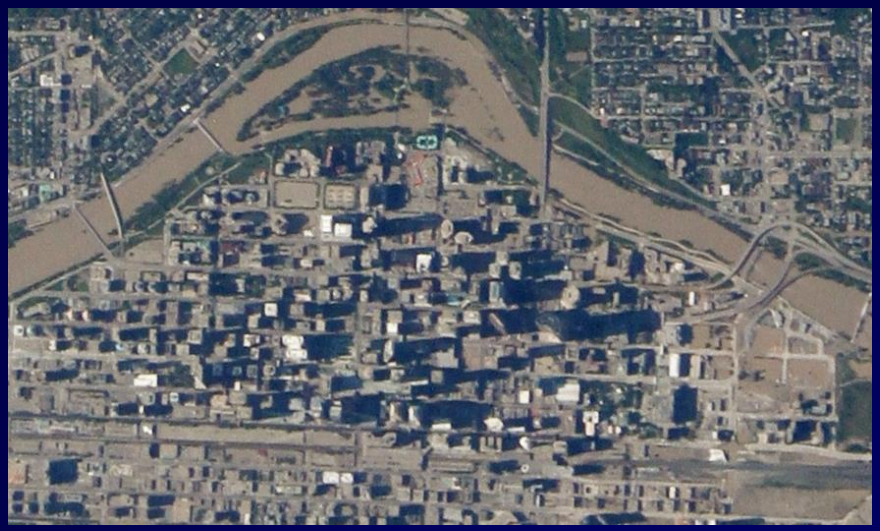
- Resources (estimated $6 B loss)
  - Life and limb first
  - $1 B immediately
  - Cash and debit cards to evacuees
  - Communication and infrastructure
  - Team of eventually 90 people across the provincial government

Flood mitigation team

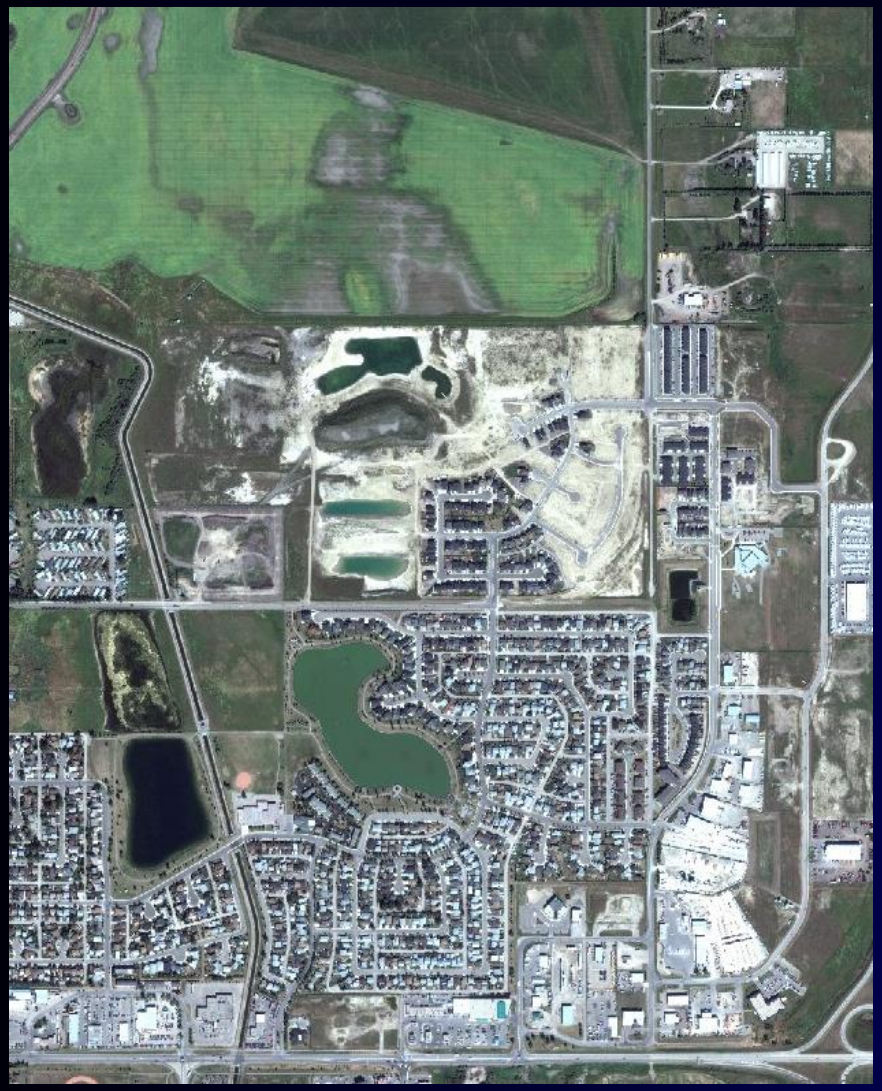
June 20, 2013: Bow River



Calgary Downtown
September 22, 2012

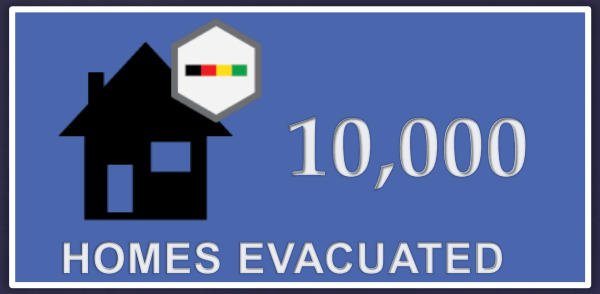


Calgary Downtown
June 22, 2013



High River September 3, 2011

High River June 22, 2013


10,000
HOMES EVACUATED

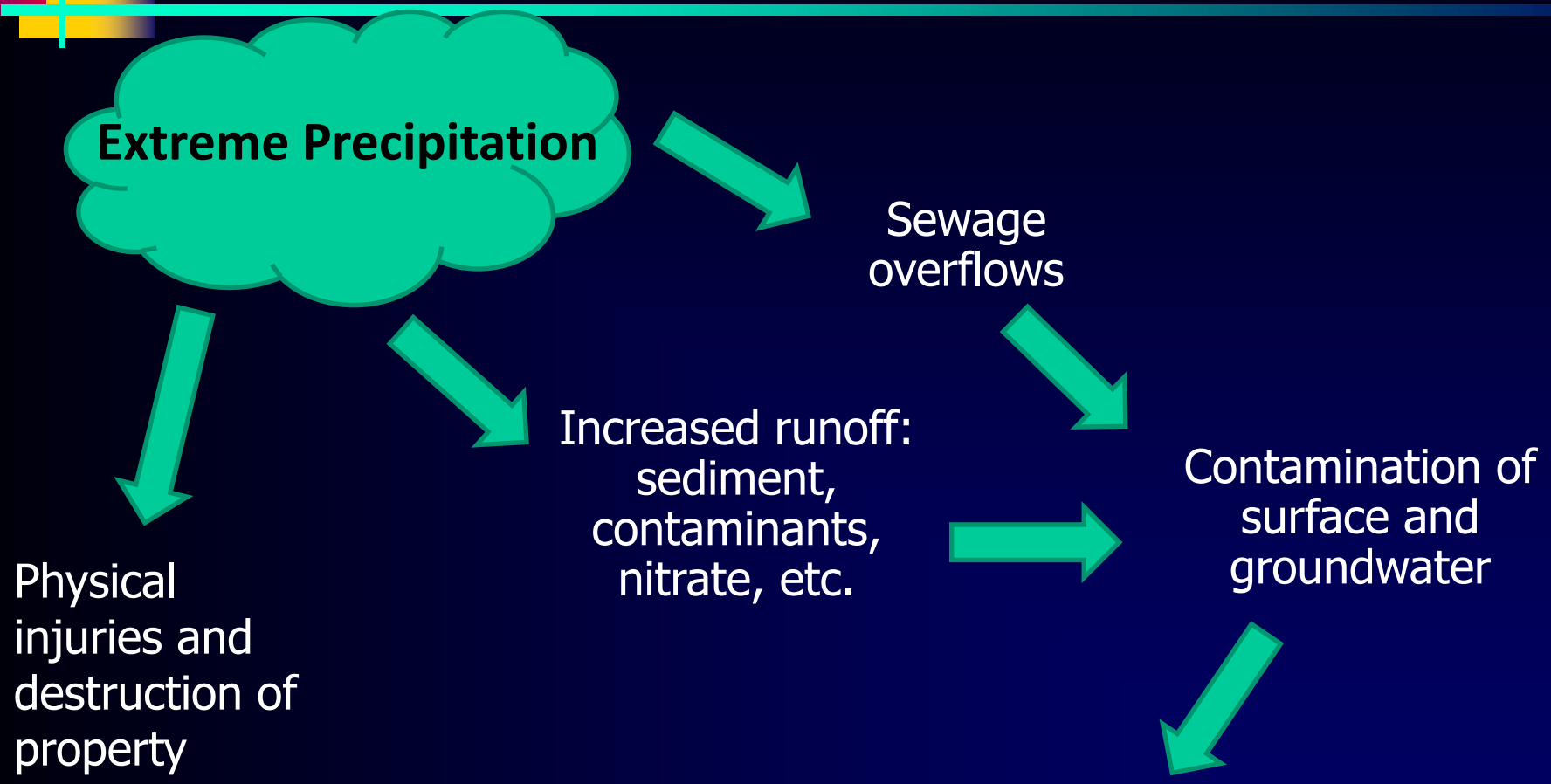
100,000
PEOPLE EVACUATED

985 KM
ROADS CLOSED

3,000
BUSINESS AFFECTED

30
BRIDGES DAMAGED

Public Health Issues - Floods



Waterborne disease outbreaks from drinking water or recreational contact (beachgoers): Giardiasis, E coli, Cryptosporidium

http://www.health.state.mn.us/divs/climatechange/docs/water_module.ppt

Funds for Flood Recovery and Mitigation

- $191 M to municipalities and First Nations for rebuilding
- $70 M preloaded debit cards or cheques to > 56,000 Albertans
- $71.5 M DRP payments (10,500 applications including 1,500 small businesses)
- $25 M mental health programs
- $216 M Flood Recovery Erosion Control grants
- $100 M transportation infrastructure
- $104 M irrigation infrastructure
- $20 M for 8 schools in High River and Calgary
- $81 M for parks, pathways, and campgrounds
- $600 M for mitigation projects between 2014 and 2017

Heroes of the Flood: more than 1300 nominees

7 Key Elements of Flood Mitigation

1) Overall Watershed Management
2) Flood Modelling, Prediction, and Warning Systems
3) Flood Risk Management Policies
4) Water Management and Mitigation Infrastructure
5) Erosion Control
6) Local Municipal Mitigation Initiatives
7) Individual Mitigation Measures for Homes

- Drought mitigation would have similar elements.
- All changes in the water physical environment will impact and be affected by social (health) and economic status.

The future outlook?

- Floods (and droughts) are a natural and intrinsic part of the hydrological cycle.
- Climate change will exacerbate these events – frequency, duration.
- During a crisis, human health/life is the primary focus.
- Preparedness (i.e. emergency response plan) is required for when they happen.
- Mitigation is the best approach for future preparation.

What are Aquatic Invasive Species (AIS)?

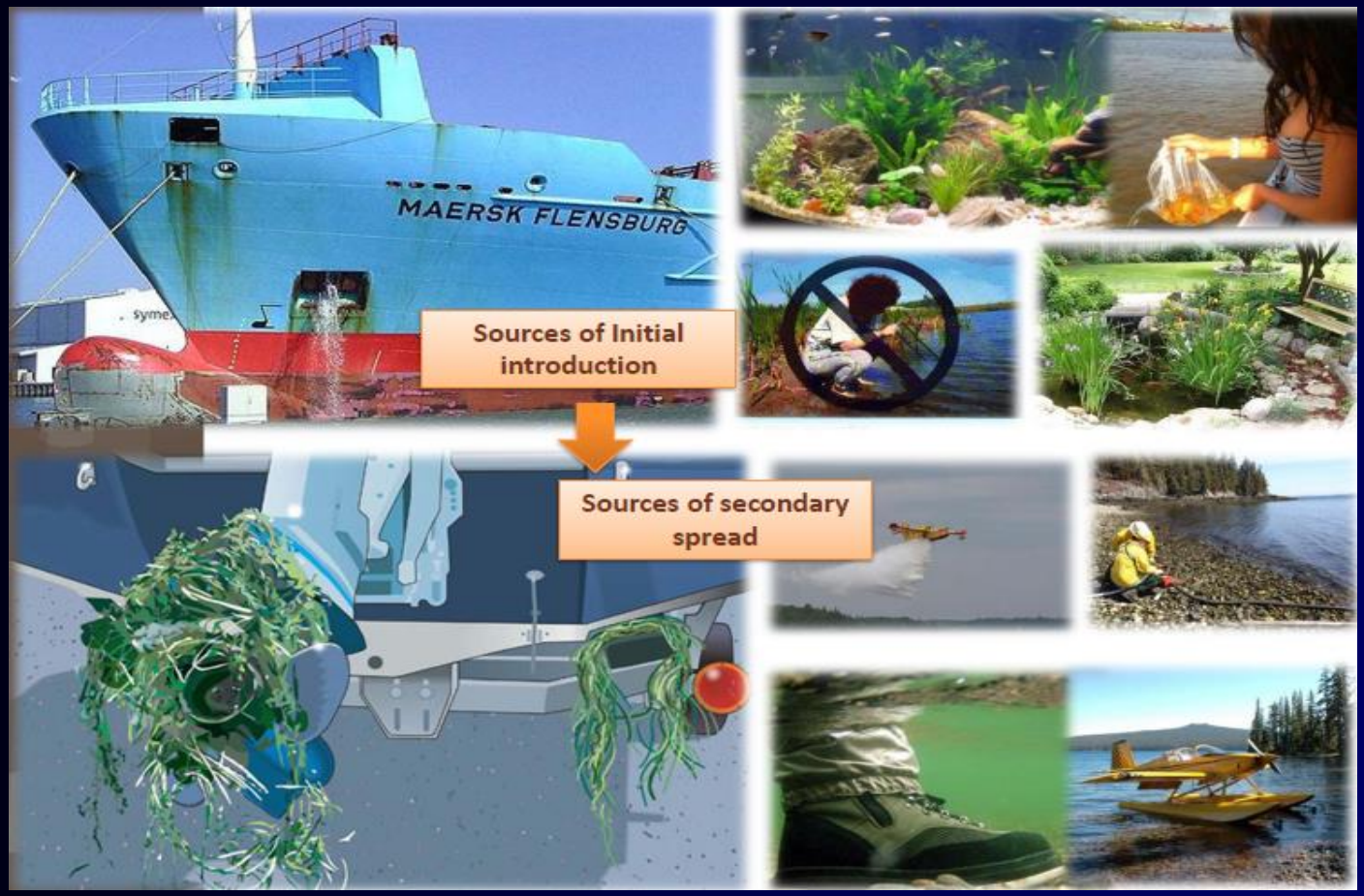
- Plant or animal species that are not native
- No effective predators
- Spread easily, reproduce quickly
- Pose significant threats to the economy, environment, and society

Purple Loostrife

Asian Carp

How are AIS introduced?

- Introduced in ballasts of cargo ships
- Spread by trailered watercraft from infested areas



A Parasite & Two Mussels

- **Whirling Disease**

Protozoan: ***Myxobolus cerebralis***

SICK FISH: The deformed head of a fish with whirling disease (R.W. Goede photo, Utah Department of Natural Resources)

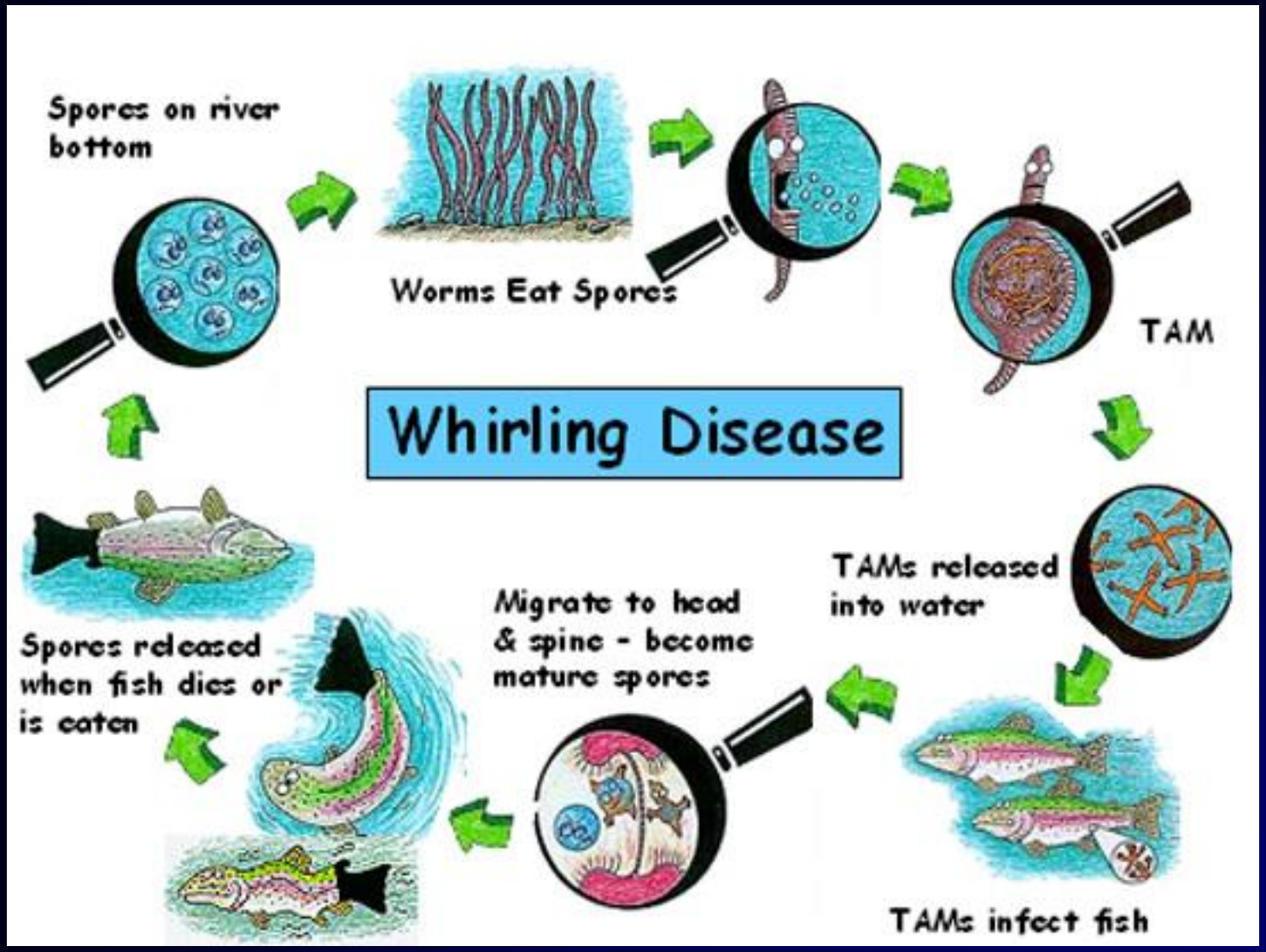
- **Mussels: zebra, quagga**

In Canada: Just found in Alberta

- Whirling disease first detected in Johnson Lake, Banff Alberta on Aug. 23, 2016
- More locations:
  - Rivers: Bow, Lower Cascade, Spray
  - Creeks: Carrot, Lott, Healy
  - A few commercial aquaculture facilities

- Trout: cutthroat, rainbow, brown, bull, brook)
- Salmon: atlantic, sockeye, coho, chinook)
- Whitefish
- Lead agency: Canadian Food Inspection Agency
- Not a risk to human health

Lifecycle: No treatment options

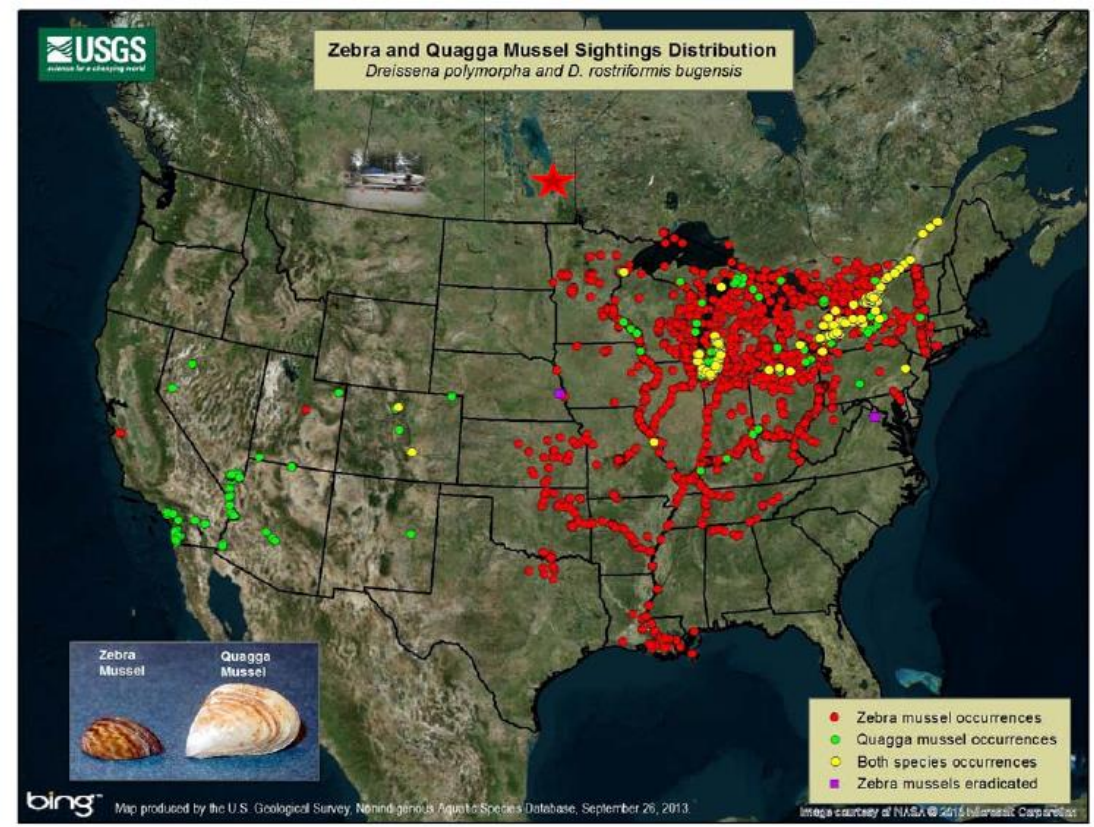


Imminent threat to AB: Invasive mussels

- Zebra and quagga mussels
- Clams are small in size (fingernail)
- One mature female can release one million eggs per year
- Live out of water for 30 days
- Attach to virtually any (hard) surface
- New generations settle on old shells
- *Native mussels don't attach!*

Not yet in Alberta: Don't move a mussel!

- Found in many lakes in the USA, where Albertans spend the winter (snow birds are a risk)
- In Canada: ON, PC, MB
- Not yet: BC, AB, SK



Impacts-Invasive mussels

Environmental and Social

- Impacts water quality
- Cause toxic algal blooms
- Outcompete native species
- Beaches littered with sharp shells

Economic

- Clog irrigation outlets/intakes, pipelines, dam operations, municipal intakes, and other water infrastructure
- Million of dollars to control in perpetuity

Alberta's AIS prevention program

- Program focusing on prevention
- Boat inspections are mandatory
- Sniffer dogs are being used at the border

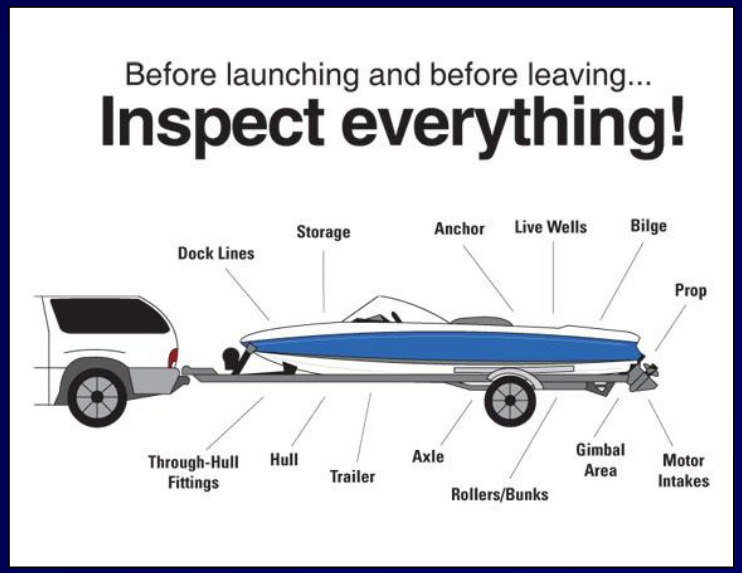
Alberta Environment and Sustainable Resource Development

What an you (public) do?

Be an advocate

Report aquatic invasive species:
1-855-336-BOAT (2628)

Clean * Drain * Dry*
-your boat and recreational gear
-pull the plug



Aquatic Invasive Species

- Humans are the vector
- Issues affect environment, society and economy
- Water resources may be devastated
- Impacts on water and food will affect human health (mental/physical)

Want to become involved in water?

Join in for notifications and organizations

- Government of Alberta newsroom
- Alberta WaterPortal newsletter
- Canadian Water Resources Association
- Oldman Watershed Council

Actions

- Promote health practices for food and water (e.g. wash and handle correctly, ensure drinking water is tested and treated)
- Reduce your impact: do not buy houses in flood plains, xeriscape your yard and reduce horticulture chemical use, do not flush medications
- Promote: Clean, Drain, Dry boats for mussel prevention

Thank you!
Andrea.Kalischuk@gov.ab.ca
Government
of Alberta