Exploring the Potential for Geothermal Energy Development in Yukon

WORKSHOP NOTES

March 10-11, 2010

Yukon College, Whitehorse, Yukon

OVERVIEW

This report summarizes the proceedings of a workshop on Geothermal Energy held March 10-11, 2010 at Yukon College in Whitehorse, Yukon. The workshop was organized in response to a number of drivers inlcuding the recent release of Yukon government's first Energy Strategy (www.emr.gov.yk.ca/energy) which identifies geothermal as a potential future energy source; the growing demand for power generation in the territory; municipal interest in heat exchange; and potential research opportunities for organizations such as Yukon College and Yukon Geological Survey.

The workshop was organized by the Yukon Geological Survey (YGS) and included representatives from government, industry and academia with an interest in geothermal energy development in Yukon. The main objective was to initiate discussions regarding knowledge and regulatory gaps that are impediments to the development the territory's geothermal resources. Participants made presentations on legislation, technical studies, and industry needs and exchanged ideas on next steps. Funding for the workshop was provided by CanNor through their Strategic Investment in Northern Economic Development (SINED) initiative.

WORKSHOP SCOPE

In developing the workshop agenda, it was recognized that while Yukon has excellent potential for geothermal energy, a number of impediments to development exist. These include gaps in geologic information to support exploration, and a lack of legislation and regulatory framework to support development. The workshop agenda was therefore very broad to allow a range of topics to be discussed. More focused discussions of each of these topics will be required before geothermal energy development becomes reality in Yukon; industry pressure and/or government policy are likely drivers of the next round of talks.

The goals of this workshop were to:

- understand industry needs;
- discuss Yukon's current and future energy requirements;
- identify gaps in geoscience information, legislation, regulations and policy that need to be addressed in order to support geothermal energy development in Yukon;
- discuss potential research opportunities for Yukon College; and
- facilitate networking among government officials, industry representatives, researchers and others.

Discussions focused on a number of questions, including:

- what geoscience and geotechnical information is required to support exploration for geothermal resources; both for heat exchange and power production)?
- how are these resources regulated in other jurisdictions?
- what are the costs and risks associated with geothermal development?
- what investment incentives exist in Canada and elsewhere?

SUMMARY OF DAY ONE DISCUSSIONS

Day one of the workshop consisted of a series of presentations. The presentations covered a range of topics and were intended to stimulate discussion and expose participants to a variety of topics ranging from the state of knowledge with respect to crustal heat flow in Yukon to some of the challenges associated with administering regulations pertaining to hot groundwater. The presenters are listed below along with a summary of key points made; copies of most presentations are appended to this report.

Bruce Carson, Director of Canada School of Energy and the Environment, University of Calgary: *"Industry Overview and Best Practices"*

- Provided federal perspective on the North and its energy needs, including federal initiatives such as the Northern Strategy and Canada's National Clean Energy Strategy
- Noted the need for Canada to adapt to Climate Change, and implications of the Copenhagen Accord
- Discussed requirements for sustainable energy use, reduction of carbon emissions, need for energy security and water quality
- Noted the need for education, training, S&T development; particularly for the North
- Cited Yukon's Energy Strategy, and our interest in a sustainable, secure energy sector
- Noted opportunities for exporting technology – e.g. carbon capture, geothermal, etc.

Carolyn Relf: *"Overview of Yukon Geological Survey"*

- YGS mandate is to provide information on the geology and geologic resources of Yukon in support of responsible resource development
- Current YGS activities do not include research that directly supports exploration for geothermal energy resources
- There is increasing pressure and funding opportunities for studies that support climate change adaptation; this could include geothermal research (e.g. compilation of heat flow data, development of a hot springs database, etc.)

Nicole Robson, Marketing and Membership Director, Canadian Geothermal Energy Association (CANGEA): *"Exploring the Potential for Geothermal Energy in Yukon"*

- Provided an overview of types of geothermal resources: geothermal energy vs. geothermal exchange
- Described CANGEA's role as an industry organization
- Noted that exploration in Canada is currently limited to British Columbia; no geothermal energy is generated in Canada at present
- Goals for Canadian development: would like to see 5,000 MW production; noted that capital cost would be ~$20B (98% of cost up-front)

Garth Thoroughgood, BC Energy Mines & Petroleum Resources: *"Advancing Geothermal Energy Development in British Columbia"*

- Presented BC Government's position regarding geothermal energy: a new Clean Energy Act will encourage investment in independent power production and recognize geothermal energy as a renewable resource with enormous potential
- Noted some of the challenges: e.g. 92% of BC's energy is already renewable, making incentives an issue
- Outlined current regulatory process:
    - Definition of geothermal is >80ºC
    - Exploration permits issued via a public tender; process is industry-driven
    - Permit provides subsurface exploration rights; no surface rights
    - A long term lease is triggered upon acceptance of a development plan
    - Drilling and production regulations were developed by the Oil and Gas Commission
    - Currently reviewing tenure referral and auction process; anticipate revised regulations by 2011
- Noted the challenge with parks: many hot springs are located in parks, precluding development opportunities

Jacqueline Hynes, Executive Council Office, Yukon Government: *"Overview of Yukon Government's Energy Strategy"*

- Distributed copies of Yukon's Energy Strategy; noted it is Yukon's first comprehensive energy strategy, released in January 2009
- Strategy looks at ~10-year horizon, and contains principles for both energy conservation and energy development
- Noted that geothermal energy is recognized as an opportunity: Yukon is in early stages; requires a policy framework
- Yukon government is considering all green energy options and supports pilot studies

Steve Grasby, Geological Survey of Canada *"Geothermal Energy Potential in Canada"*

- Provided global overview of energy consumption: approaching peak of oil production in spite of growing demand
- Noted that geothermal energy is more reliable than other renewable energy sources
- Presented heat flow map of North America (Blackwell and Richards, 2004); GSC estimates Canada's in-situ geothermal energy potential is 200,000 BBO equivalent
- Noted that Canada lacks geothermal energy resource assessments and has limited information on environmental impacts and risks; technology is another science gap
- Yukon has very little heat flow data: heat flow mapping generally is at a very coarse scale in Canada (e.g. Jessop 2008; Grasby et al 2009; Majorowicz and Grasby 2010; Majorowicz and Grasby *in press*)
- GSC is focused on documenting ages of volcanoes and assessing thermal springs as potential exploration tools

- Noted that it would be a useful contribution to the national database if companies could insert temperature probes into diamond drill holes (as done for oil and gas wells)

Hector Campbell, Yukon Energy Corporation: *"A Perspective on Energy Development Opportunities in Yukon"*

- Yukon Energy Corporation (YEC) has a growing interest in geothermal energy; their current plan for the 2015+ timeframe includes geothermal
- Energy load forecasts have increased due to new mines; non-mine growth projections are significant as well
- By 2015 hope to be 100% renewable energy
- In 2008 hired EBA Engineering to assess geothermal energy potential of Yukon
- Recognize Dawson Ranges as a challenging area (isolated and high energy demands if Casino comes on stream)
- Geothermal power is appealing due to reliability; however up-front costs are high; YEC likely to seek partners to share risk
- Noted implementation of Independent Power Producer policy this year and net metering
- Noted that land tenure is an issue (would like to see fee simple land tenure under installations)

Stephan Klump, EBA Engineering: *"Overview of EBA studies"*

- Outlined steps in geothermal development:
    - recon scale (remote sensing, geochem sampling of large area)
    - pre-feasibility (focused area; targeted drilling, airborne thermal infrared mapping; have found visual surveys of open water useful in spring)
    - feasibility (including regulatory groundwork)
    - resource development (deep well)
    - power plant

"Jarvis River Case Study"

- site located btwn Haines Junction and Kluane Lake
- Did ground mag to image subsurface geology
- Surface pools 8-18ºC; calculated sub-surface temp ~100ºC
- Dated water at ~30K
- 2nd well to measure geothermal gradient hit artesian acquifer before reaching bedrock
- next step: determine overburden thickness in order to plan new drill hole into bedrock (GPR? Seismic?); need to drill ~300m into bedrock to measure geothermal gradient

"Takhini Hot Springs Study"

- spring at surface is 46.5ºC, 6.6l/s flow rate; current use is bathing and heating
- investigated power generation potential in 2008-09
- geothermometric calculations suggest source is between 100-170ºC: suggests possible mixing of more than one source

Chad Gubala, Yukon Cold Climate Innovation Centre, Yukon College: *"Energy Innovations for the North"*

- YCCIC mandate is the foster technology development and business opportunities for Yukon

- Responding to federal interest in applied science
- College wants to see an expanded knowledge-based economy
- YCCIC projects include Stirling Engine Program, Transportation R&D, permafrost and BST surfaces, Hydro-kinetic Generation Program, ICT and Sensor Development and Integration
- YCCIC keen to support graduate students

Gwen Holdman, Chena Hot Springs Resort and Rebecca Garrett, Alaska Energy Authority: "*Chena Hot Springs Geothermal Power Plant*"
(Presented by Chad Gubala)

- Chena Hot springs is an off-grid resort: previously was entirely diesel powered
- Well situated to take advantage of a swath of hot spots south of Brooks Range: rocks are vertically fractured, permeable, have high radiogenic signatures
- Exploration drill holes and water chemistry produced a promising temperature cross section: data indicated 7 MW capacity
- Pilot project undertaken in partnership with Univ of Alaska Fairbanks
- 400KW facility built: provides power and heat for 44 buildings and greenhouse
- Noted that YCCIC would like to undertake a similar pilot project

SUMMARY OF DAY TWO DISCUSSIONS

Discussions on Day 2 focused on the next steps required to advance geothermal development opportunities in Yukon. Ideas fell into three general categories. The first was related to the need for a pilot project to prove the viability of Yukon hot springs for power generation. The second focused on the need to provide background geologic information to support exploration efforts and reduce risk. The third was the need to fill the legislative and regulatory gaps in order to provide investment certainty. The discussions are summarized below.

Proof of Concept Pilot Project

A number of potential pilot projects were discussed. The Takini Hot Spring site was identified as a good candidate for such a test, given its proximity to the grid, the potential interest of the owner, and the parallels to Chena Hot Springs. YCCIC expressed interest in taking the lead to seek research funding for a proof of concept study at Takini: if successful, it could catalyze interest in other developments in Yukon. Other potential pilot project sites might include off-grid exploration sites that have plans for mine development (e.g. Howard's Pass). A number of sites are being studied by Yukon Energy Corporation.

Geologic Information to Support Exploration

A number of recommendations came out of the discussion of geologic information gaps, including:

- YGS and/or GSC should create a Yukon-wide geothermal prospectivity map; starting point could be a map showing hot springs and recent volcanoes (points), extensional faults (lines) superposed a radiometric backdrop.
- Yukon government should encourage mineral exploration companies to measure geothermal gradient when drilling (look into whether such data could qualify for exploration credit)

- Studies should concentrate on areas near existing power grid, adjacent to communities and near proposed new mines

Development of Legislation and Regulation for Yukon

- Yukon government needs to develop legislation to enable geothermal developments: should look at adjacent jurisdictions
- Given that 25% of Yukon's contribution to greenhouse gas emissions are from heating, Yukon government should include geothermal exchange in its energy strategy
- Need to consider issues/barriers such as surface land tenure, social licence, conflicting land use, overlapping subsurface rights (e.g. mineral rights vs. hot groundwater)
- YESSA and YG will need to understand environmental impacts in order to permit

NEXT STEPS

The following next steps were agreed upon by workshop participants:

1. A draft report summarizing the workshop will be generated and circulated to participants
2. Workshop presentations will be shared with participants (see appendices)
3. Carolyn will brief Energy, Mines & Resources policy staff regarding workshop discussions and implications.

Upon review of the report, workshop participants will decide whether to release the workshop report publicly.

REFERENCES

Blackwell, D.D. and Richards, M., 2004. Geothermal Map of North America, American Association of Petroleum Geologists, 1 map sheet, 1:6,500,000 scale.

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Grasby, S.E., Majorowicz, J. and Ko, M., 2009. Geothermal Maps of Canada, GSC Open File 6167

Jessop, A., 2008. Review of National Geotheraml Energy Program, Phase 2 – geothermal potential of the Cordillera, GSC Open File 5906.

Majorowicz, J. and Grasby, S.E., 2010. High potential regions for enhanced geothermal systems in Canada. Natural Resources Research. DOI: 10.1007/s11053-010-9119-8

Majorowicz, J. and Grasby, S.E., *in press*. Heat flow, depth-temperature variations and stored thermal energy for enhanced geothermal systems in Canada. Journal of Geophysics and Engineering.

APPENDIX A: List of Workshop Participants

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APPENDIX B: Copies of Presentations

The attached copies of presentations are provided with the approval of workshop presenters. For permission to use these slides or reproduce graphics please contact the original authors.

Yukon Geological Survey Overview

Carolyn Relf

Resources

- 27 Staff (20 geologists, 4 technical support, 2 client information services)

- $1,305K operating budget

- "soft" funding for targeted projects

YGS Activities

- Bedrock and surficial mapping
- Basin studies
- Geophysical surveys
- Metallogeny
- Mineral services/liaison
- Permafrost monitoring
- Community mapping
- Hazards studies
- University research

YGS Mapping Program

2009-10 mapping:

- 4 bedrock
- 2 surficial
- 5 aeromag

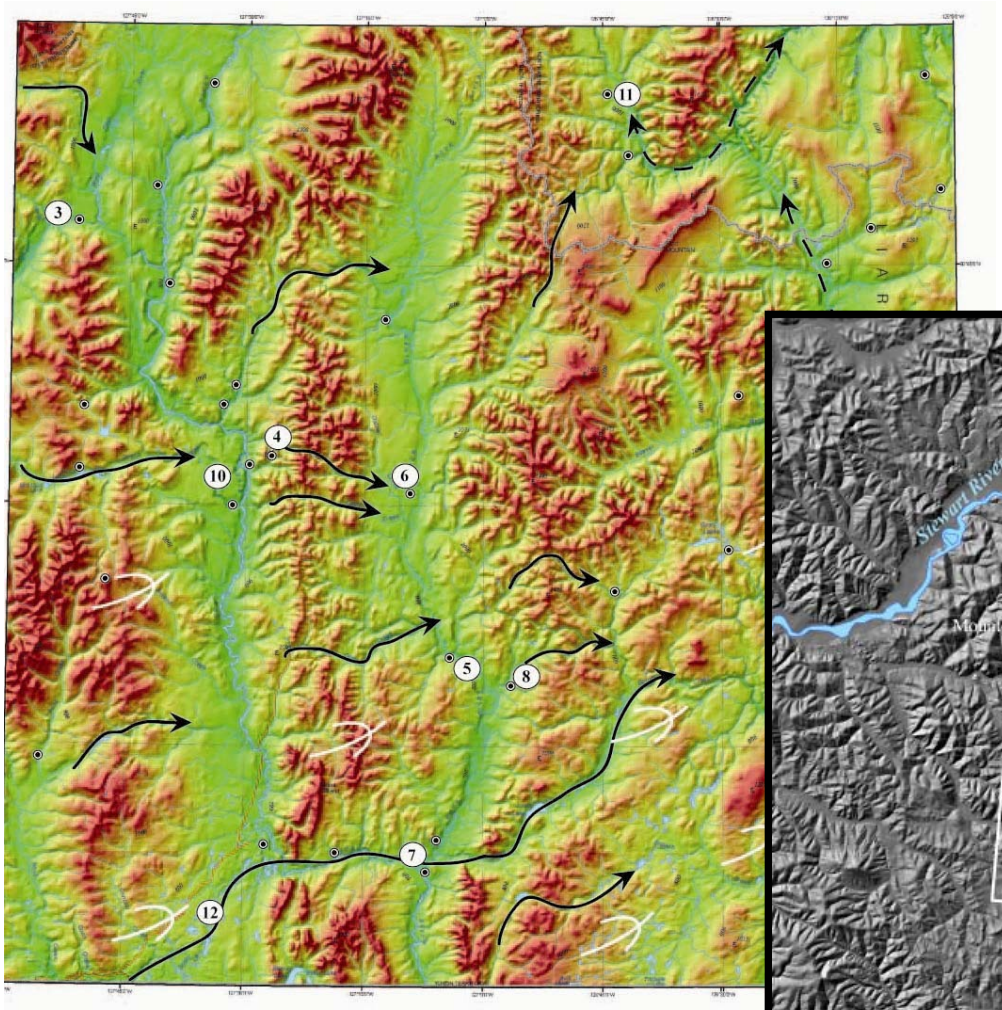
- Bedrock mapping and thematic studies

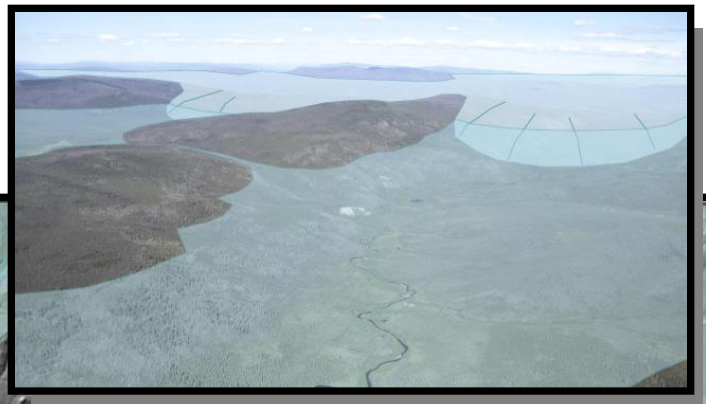
-Targeted petroleum studies

- Documentation of glacial limits

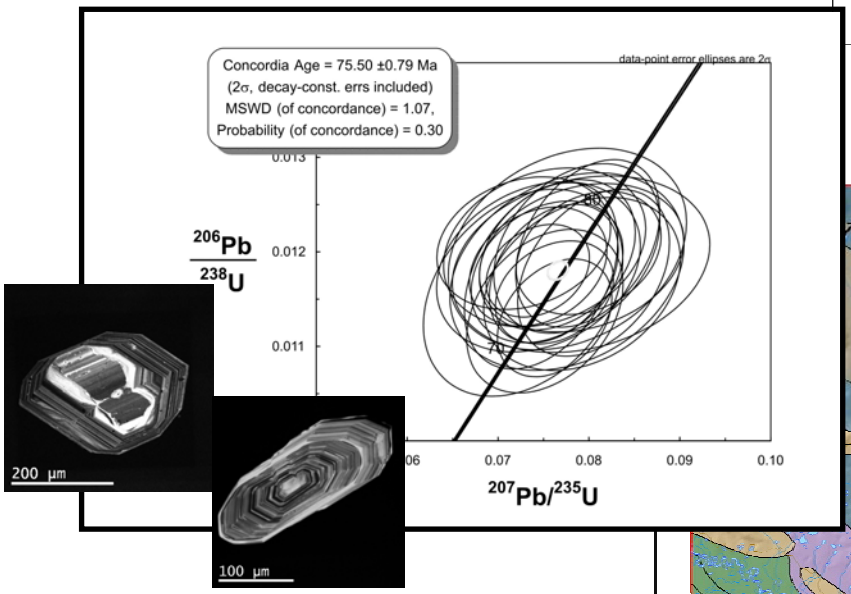
- Collection of geophysical data (mag, radiometric, conductivity)

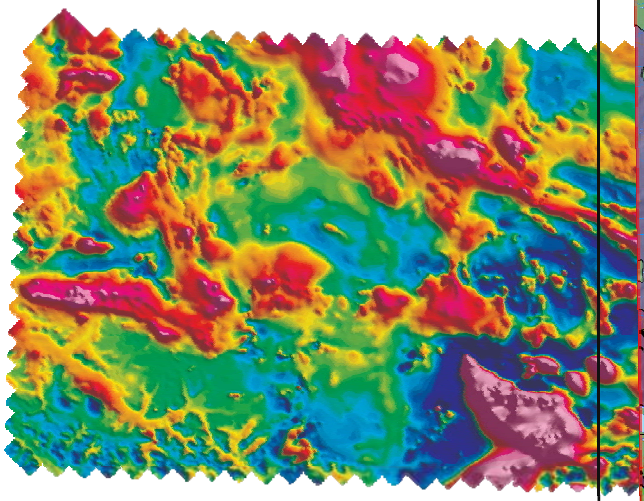
Surficial Geology

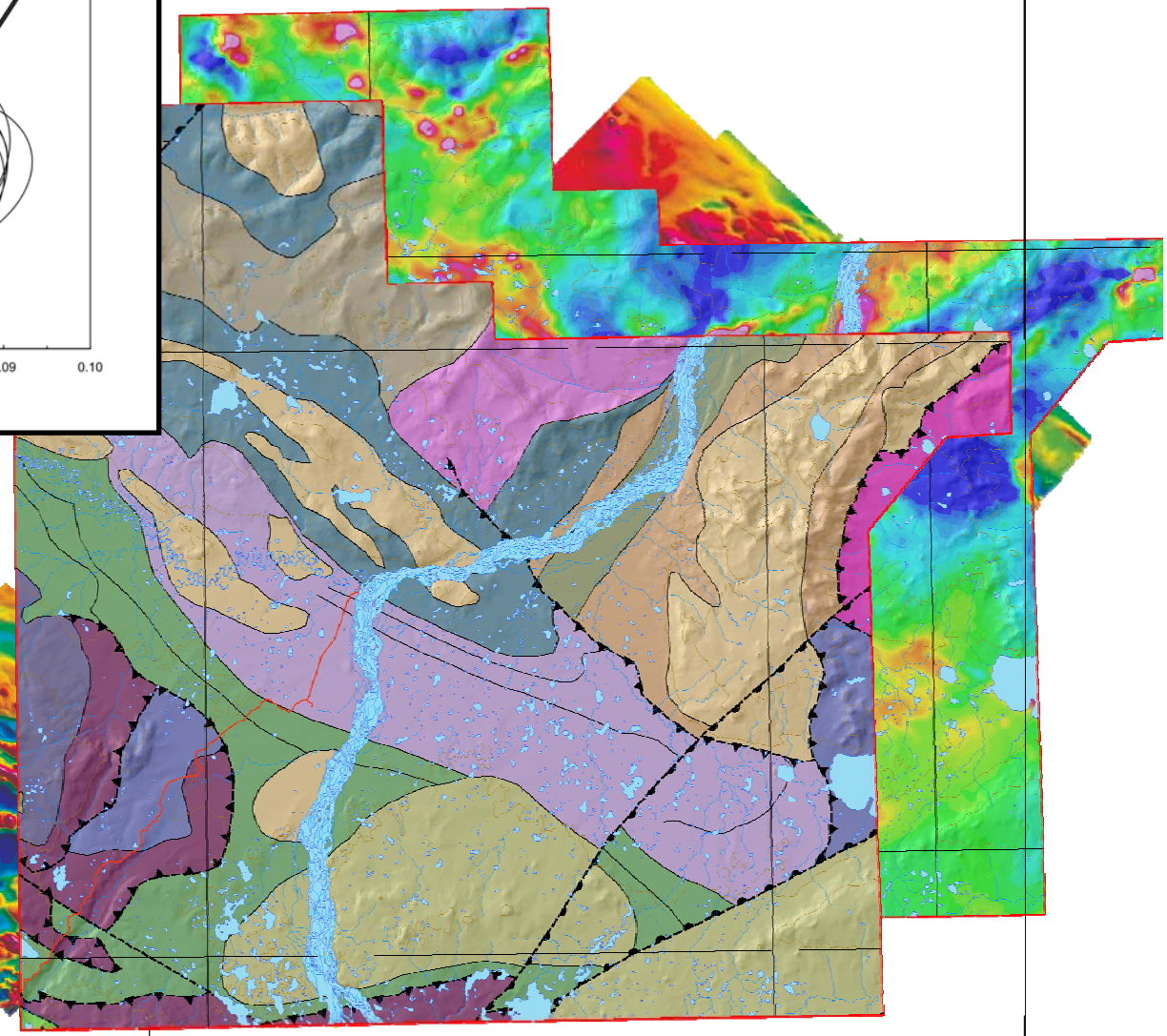




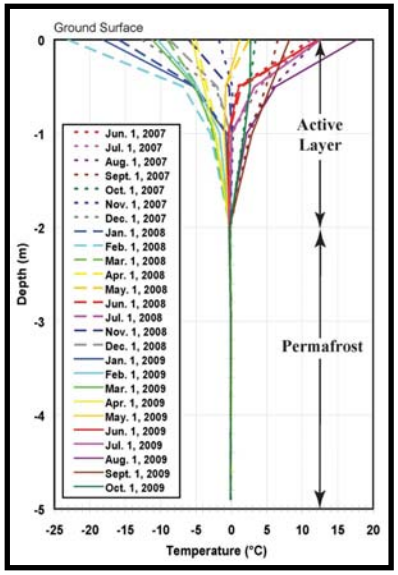
Bedrock Geology

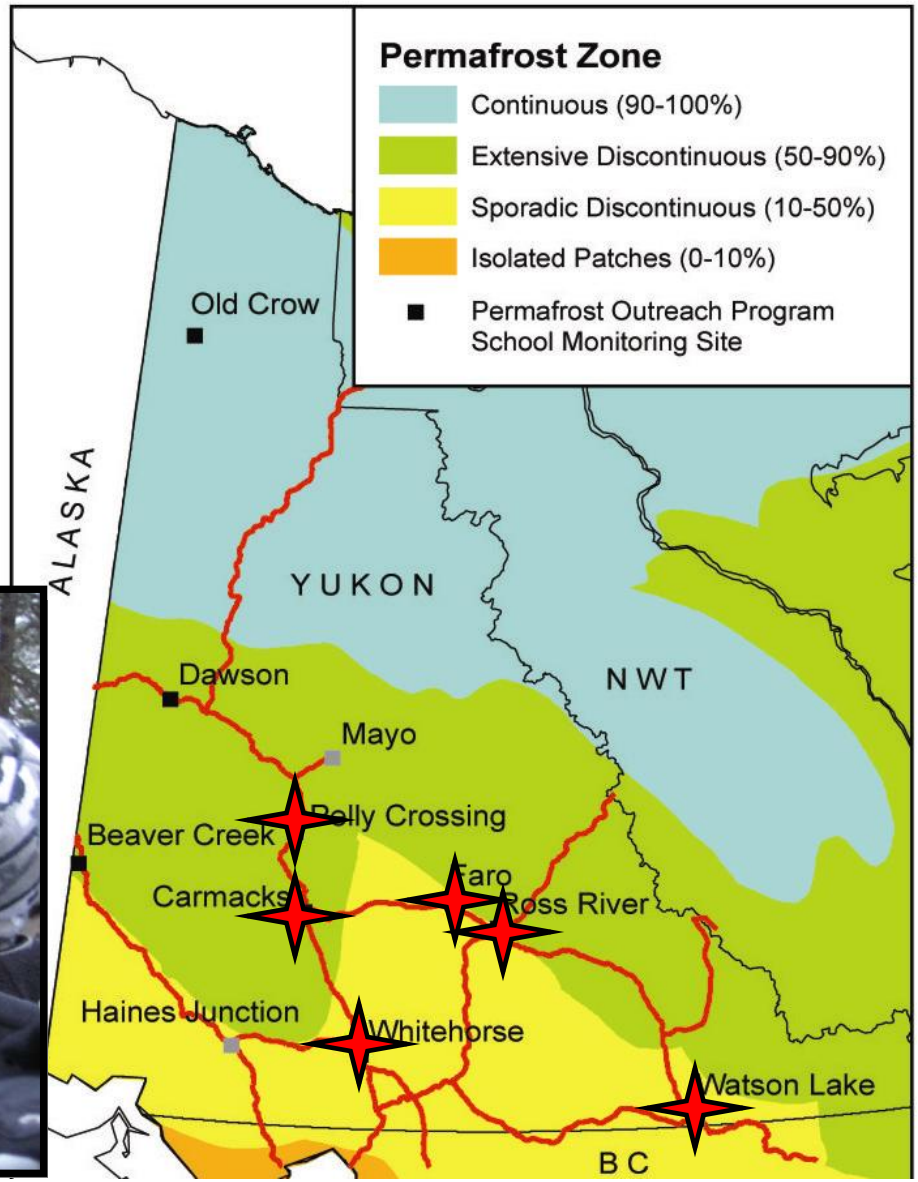






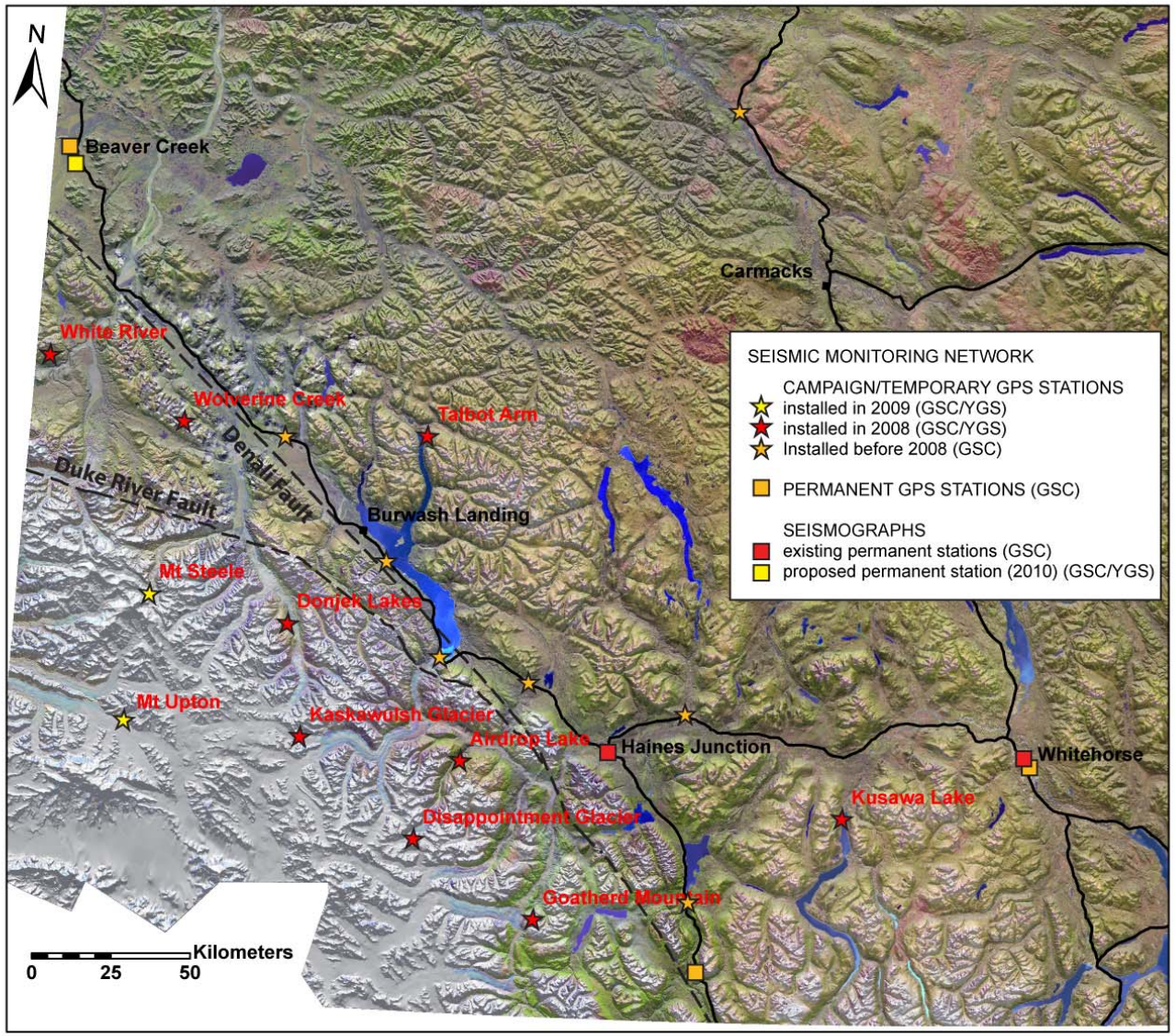
Permafrost monitoring





Neotectonics

Collaboration with GSC's Hazards Program



Landslide Monitoring

Little Salmon Lake Landslides

Mineral Services

- Visits to exploration sites and placer operations

- Yukon Mining Incentives Program

- Core Library

- Mining & Petroleum Environmental Research Group

- Technical advice to industry

Outreach

Looking Forward

- Increasing pressure and funding opportunities for research in support of climate change adaptation

- Yukon Energy Strategy

- Increased liaison with other YG departments (e.g. Highways & Public Works)

- Ground water?

- Geothermal information?

- Baseline geochemical data

CanGEA

CANADIAN GEOTHERMAL ENERGY ASSOCIATION

Exploring the Potential for Geothermal Energy in Yukon

March 10/11, 2010

Nicole Robson
Marketing and Membership Director
Canadian Geothermal Energy Association

CanGEA
CANADIAN GEOTHERMAL ENERGY ASSOCIATION

CanGEA Members (35)

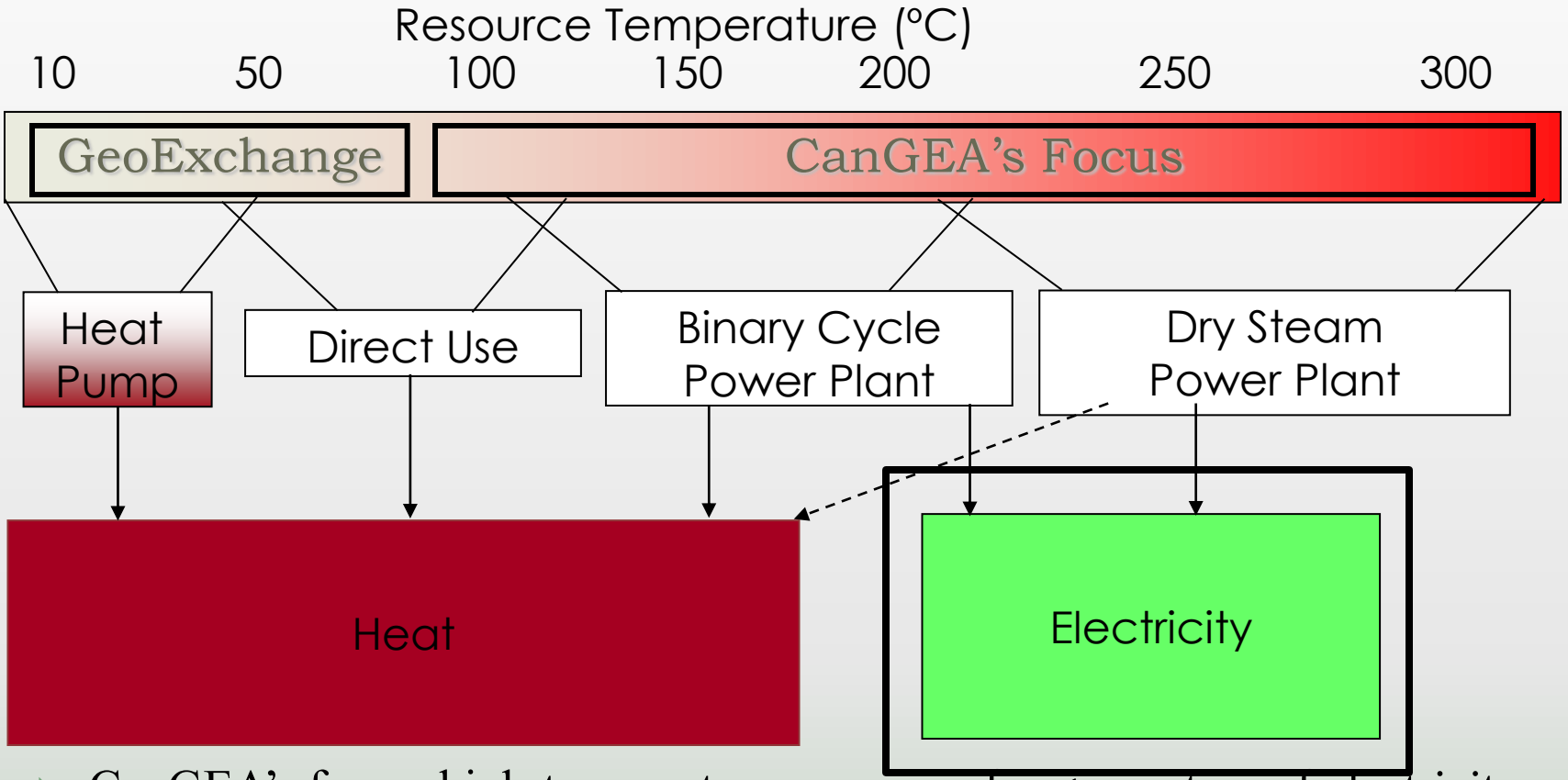
BORDEN LADNER GERVAIS
Chevron
ENBRIDGE
TMX Toronto Stock Exchange | TSX Venture Exchange
magma ENERGY CORP
nexen
ORMAT
GRADIENT Geothermal
SUNCOR ENERGY
YUKON ENERGY
SOMERVILLE
ThermaSource GEOTHERMAL CONSULTING AND DRILLING
Íslandsbanki Specialists in Geothermal Financial Services
Savanna Drilling
BOREALIS GEOPOWER
Blakes LAWYERS
SGP
MANNVIT ENGINEERING
DUNDEE WEALTH MANAGEMENT Dundee Securities Corporation
NGP NEVADA GEOTHERMAL POWER
MERIDIAN ENVIRONMENTAL
Ram Power, Inc.
MAINSTREAM RENEWABLE POWER
BEACON HEAD ENERGY LTD.
CLARK WILSON LLP BC's Law Firm for Business
Ruinril Petroleum
WELLINGTON WEST
CALDERA GEOTHERMAL
GLACIER Partners
GeothermEx, Inc.
SKM
JACOBSECURITIES inc

What is CanGEA?

CanGEA was established in 2007 as an industry association to promote the emergence of the Canadian geothermal power industry

- Active in discussion regarding Canadian geothermal policy at the Federal and Provincial level
- Leader in advocacy for geothermal as a clean, sustainable and affordable power
- Working to create an awareness and reconcile issues surrounding Canadian geothermal power
- Unify Canada's community of geothermal proponents

Types of Geothermal Resources



- CanGEA's focus: high-temperature resources for generation of electricity
- These resources contain hot water and steam
- Turbine technology can efficiently turn this heat source into electricity

Geothermal Energy Uses

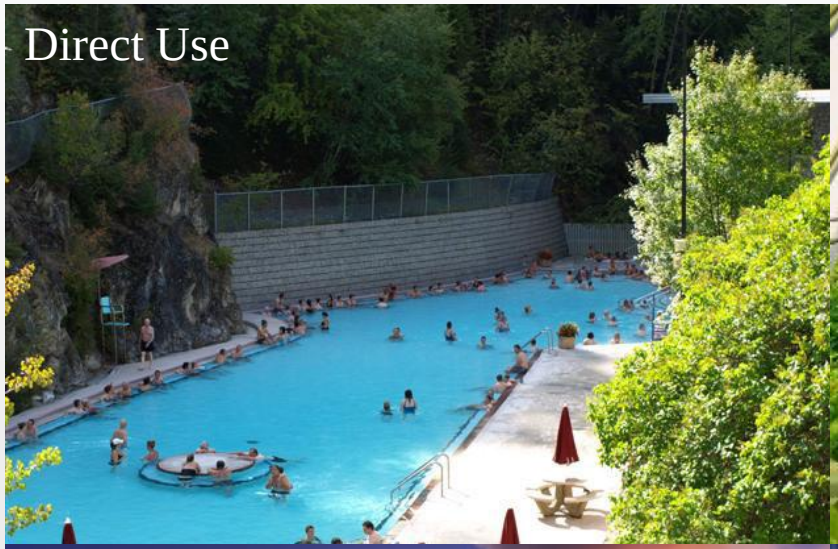
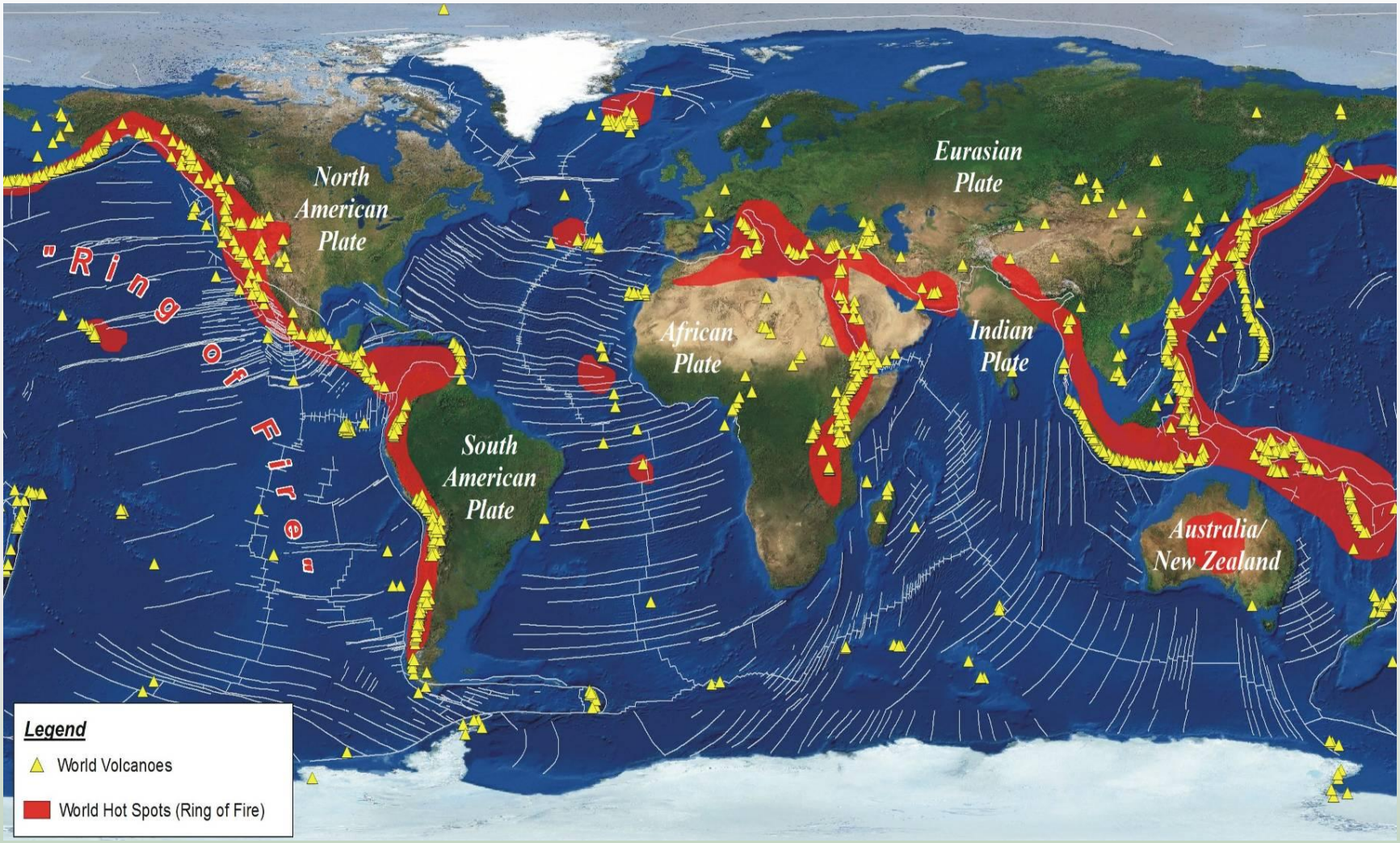
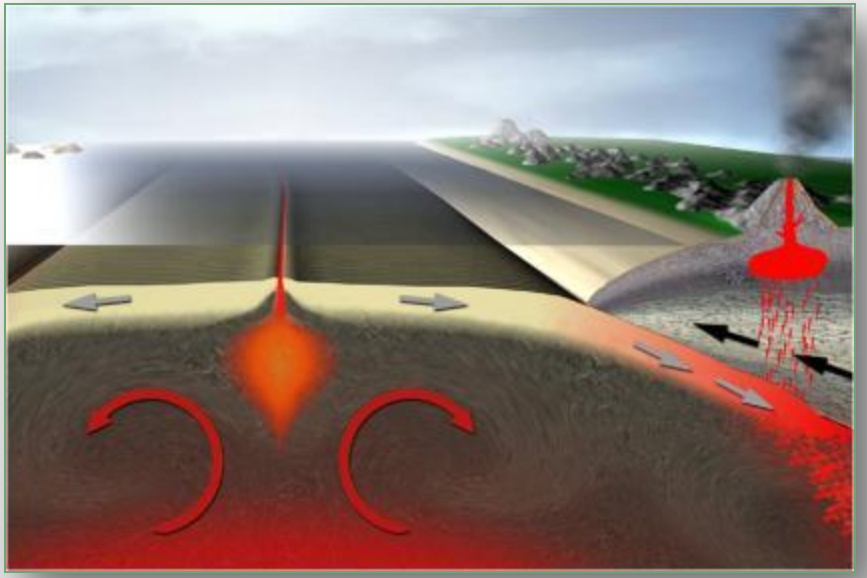


Plate Boundaries



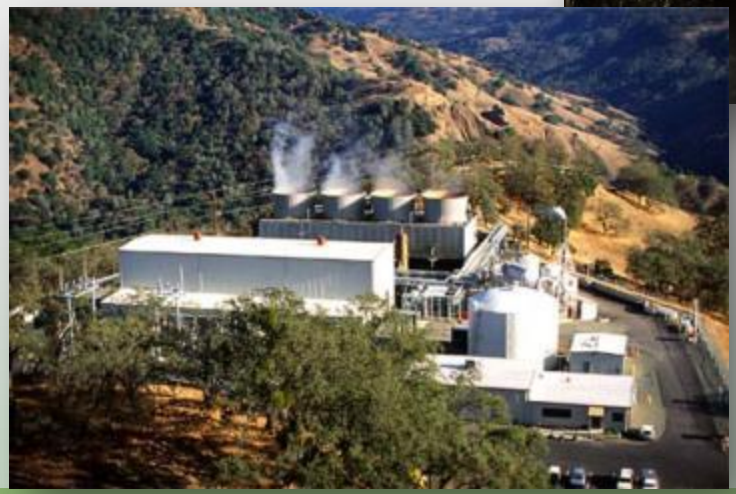
Geothermal Opportunities



- Geothermal energy opportunities focused on plate boundaries
- Heat resource closer to surface!

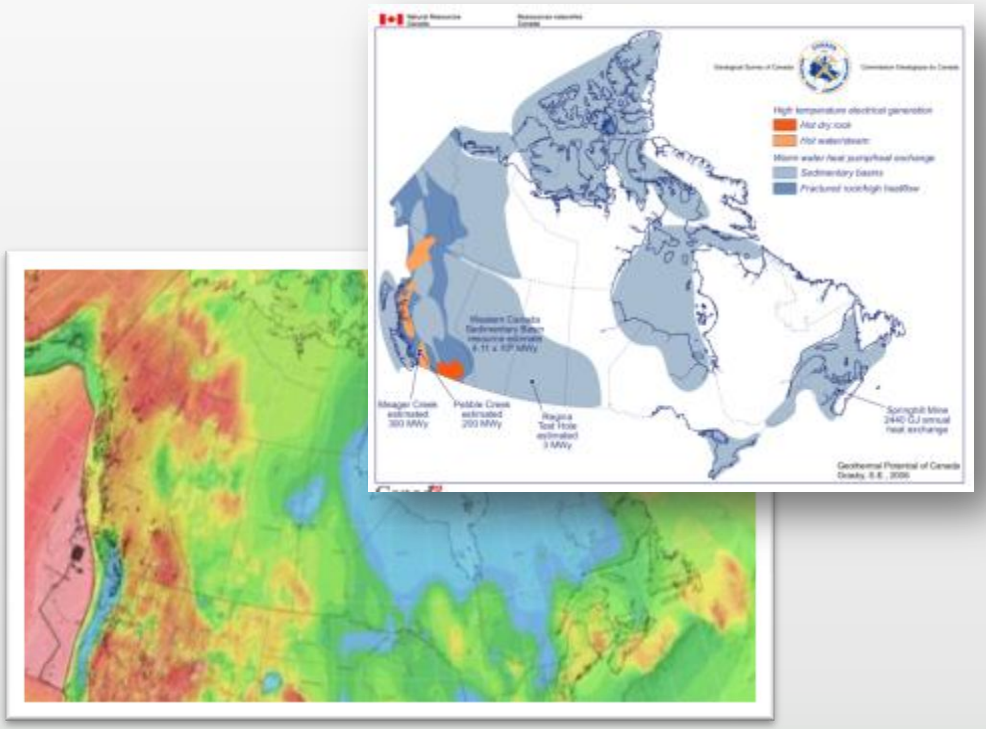
Power Source -Worldwide

- >3,400 MW in US Market
- Iceland
- Latin America
- Larderello, Italy



>10,000 MW in 24 countries supplying 60 million people with renewable energy

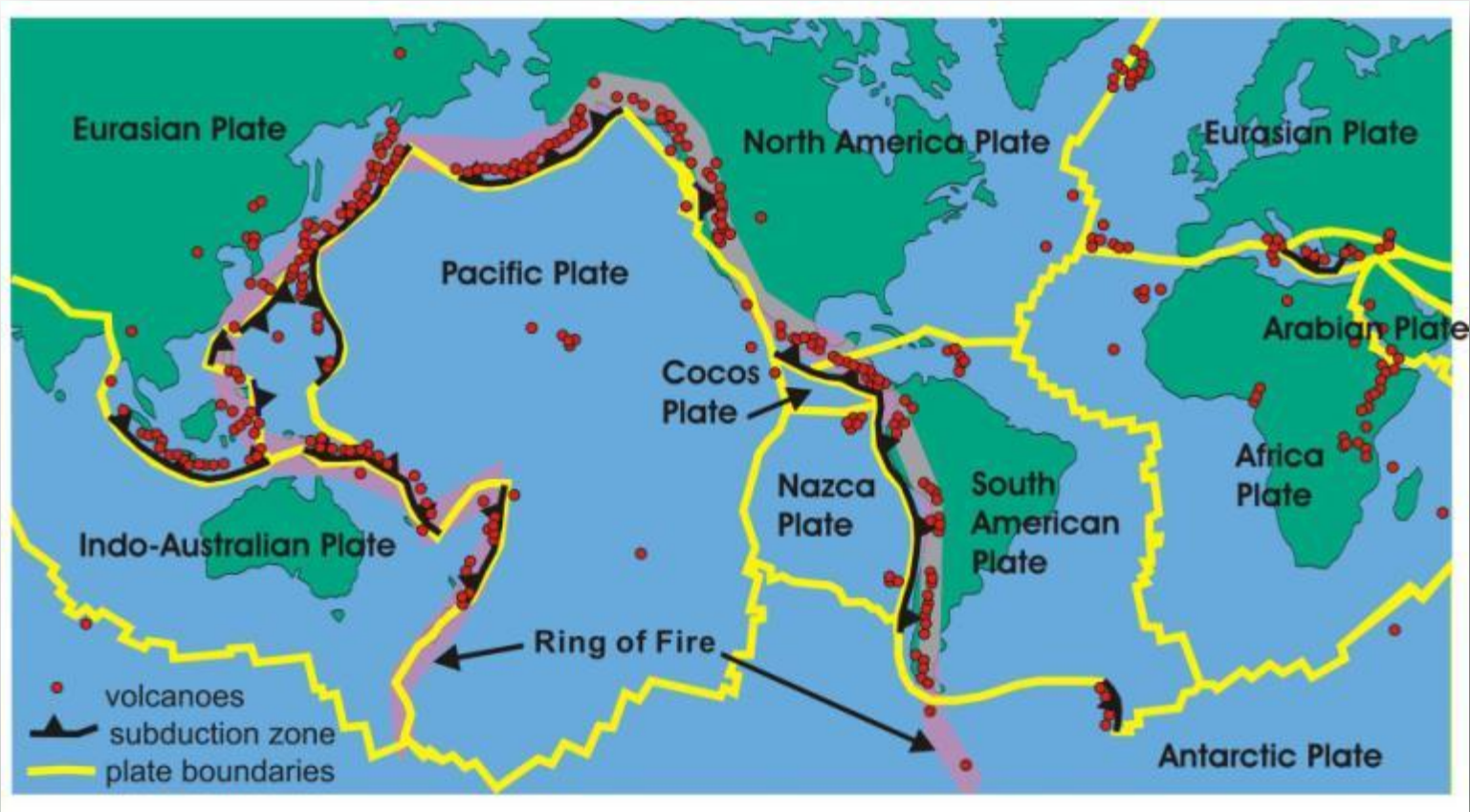
Canadian Geothermal Energy Potential



- 4-7 GW of potential power in Canada ?
- 1 MW would supply 782 Canadian homes
- Hydrothermal, Mining, Oil & Gas, EGS, GeoExchange
- Untapped, clean, power source for Canadians

- ***Electrical energy from geothermal resources is officially classified by Natural Resources Canada as a 'renewable' energy, meaning that they operate without destroying finite natural resources.***

Western Canada on Pacific Rim of Fire



Mapping of Plate Tectonics and Recent Volcanism: Correlates with Geothermal Energy

Economics of Geothermal

- Geothermal has significant upfront costs
- Exploration and development, make up the majority of costs accrued over the life of the plant
- The operation and maintenance (O&M) accounts for small percentage of total costs
- Geothermal resources (hot water & steam) cannot be transported long distances and electricity is generated on-site
- Development facilities are located at the site of the resource

Geothermal Investment

- US: Looking to develop 5,600 MW of geothermal energy
- Create 30 year economic output of ~$85 billion
- US DOE - For every dollar invested in geothermal energy, the resulting growth of output to the U.S. economy is $2.50
- "$1.00 invested = $2.50 output to economy"
  - 10 MW geothermal facility
  - At $4-5 million/MW = $40+ million investment
  - DOE estimates = ~$100 million

Employment

- In 2004, US geothermal industry supplied:
  - 4,583 direct power plant related jobs,
  - 11,460 full-time jobs direct, indirect, and induced
- Example: 10MW Geothermal Power Plant
- Employment – ~42 Fulltime jobs/160 person years (p-y*)
- Wages paid to geothermal employees often circulate back through the community

Canada's Geothermal Potential

- 5,000 MW
- ~43,000 GWh of Firm Power
- $20 Billion in Capital investment
- ~ 30,000 person years of manufacturing and construction employment
  - 6 person years of manufacturing and construction employment per MW
- ~ 9000 permanent jobs
  - 1.8 permanent jobs per MW

Recent Financial Activity

magma ENERGY CORP	$184 Million	IPO & Private Placements
Ram Power, Inc.	$180 Million	Equity Financing
SGP	$12 Million	Private Placements
NGP NEVADA GEOTHERMAL POWER	$61 Million	US Government Grants
BOREALIS GEOPOWER	$12 Million	CND Government Grants

Even in a difficult market, the geothermal industry has continued to raise new capital

- One thing all of the above companies have in common - they are CanGEA Members
- Through policy activity, networking support and a multitude of other initiatives, CanGEA members receive significant exposure in the geothermal community and beyond.

CanGEA Members Receive US DOE Support

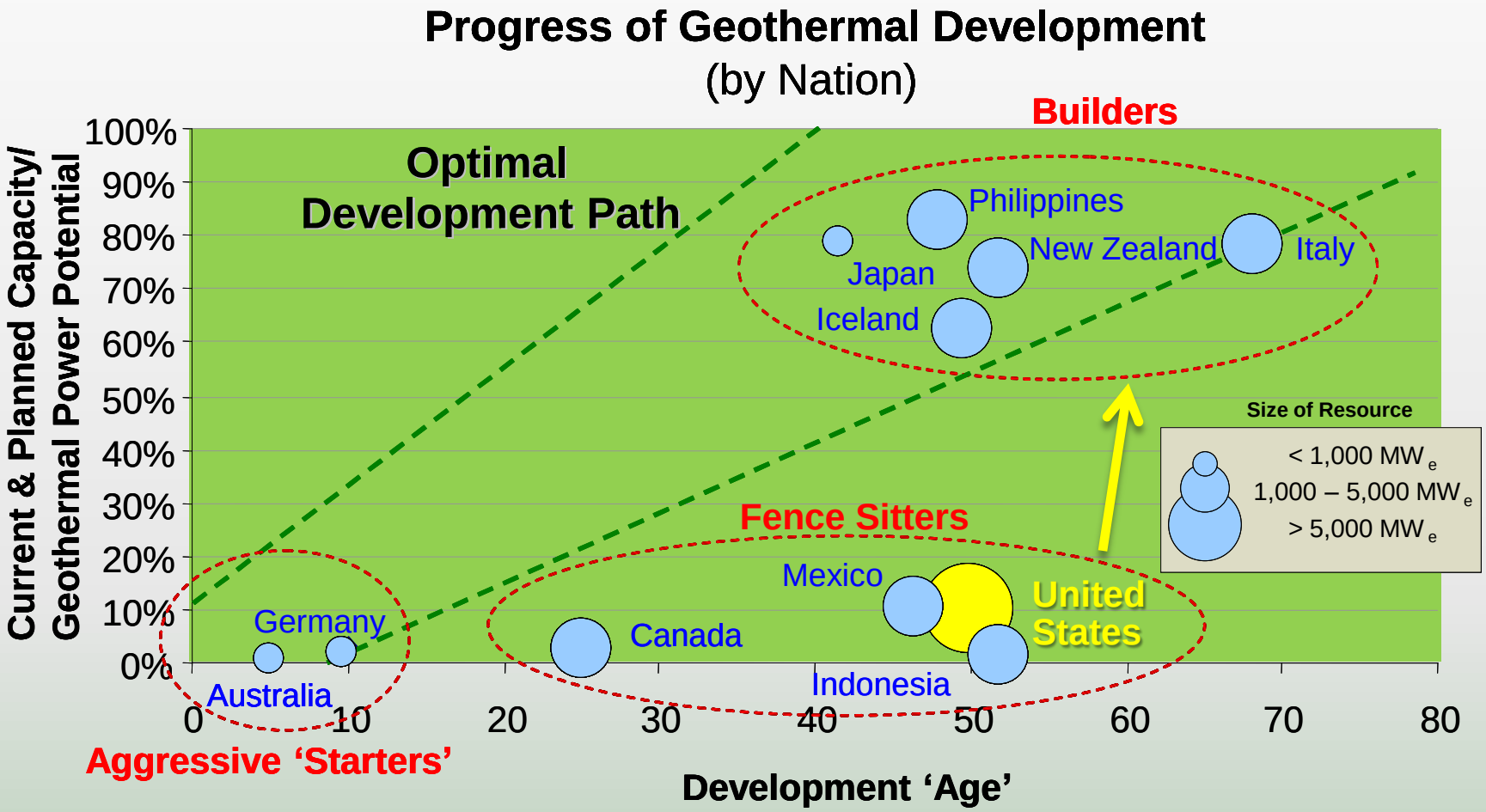
magma ENERGY CORP	**$10 Million**	Innovative Exploration & Drilling
Ram Power, Inc.	**$5 Million**	Innovative Exploration & Drilling
SGP	**$10 Million**	Innovative Exploration & Drilling
ORMAT	**$13.76 Million**	Innovative Exploration & Drilling
OSKI ENERGY	**$4.21 Million**	Innovative Exploration & Drilling

Why Aren't There Any Projects in Canada?

There are fiscal, non-fiscal, technical, and non-technical reasons why Canada doesn't have any operating fields:

- Too remote
- Lack of transmission access
- Energy source is relatively new to Canadians
- Other energy sources have been historically less expensive
- High front end cost
- **Policy doesn't exist or isn't effective**

General Findings: Policy Matters

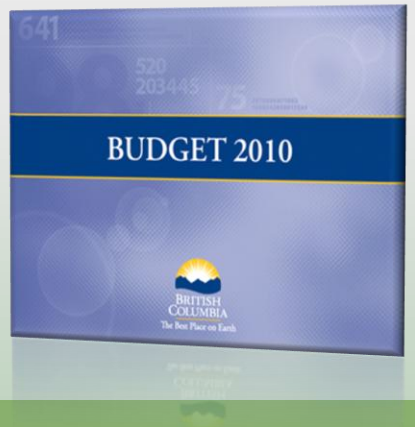


How do the Provinces value Renewable Power?

- Ontario:
  - Solar Photovoltaic Power Feed-In-Tariff
  - $635/ MWh
  - At this price, EGS would be economical AND supply base-load power
  - Co-produced fluid geothermal electricity (CPF) would also be economical with this FIT, leading to new value in Ontario's O&G infrastructure
- British Columbia:
  - Feed-In-Tariff: Renewable Power Projects Under 10 MW
  - $73-$87/ MWh

British Columbia Policy

- Province has earmarked $100M for Clean Energy initiatives including new power generation with specific mention of geothermal power
- Of the $47M already committed to renewable energy projects, geothermal power projects have yet to receive any funding
- Oil & Gas and Mining industries continue to receive incentives, including;
  - Flow-through share program extended for 3 more years
  - Oil & Gas stimulus package (2% royalty relief program)
  - Oil & Gas rural road improvement program ($51M)



British Columbia Policy

- First geothermal tenure auction since 2004 will be held March 29, 2010 (Knight Inlet parcel)
- Subsequent auctions to be held in June, September 2010
- BC has reopened requests for tenure
- The Province is working with CanGEA and industry to streamline auction process and make more sought-after land available
- Policy reform still needed in Calls for Power and transmission access (standing offers, open calls for power)

Renewable Power Incentives

Current Federal Government Incentives

WPPI	RPPI/ecoEnergy	GPPI
$256 Million	**$1.3 Billion**	**???**

Clearly, there is an "**activation energy**" that precludes the growth of renewable energy technologies . Geothermal energy is no exception, a commitment is required on the part of government to catalyze investment and early interest in development.

Government Grants

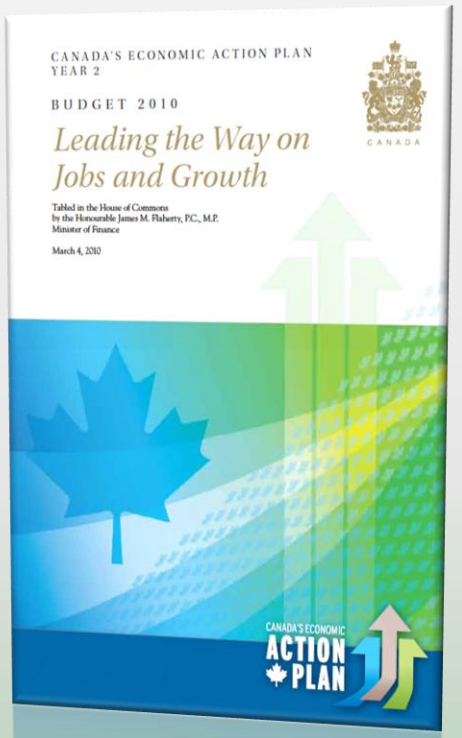
- CanGEA Member Borealis GeoPower
  - **$10-20 Million** from Natural Resources Canada Clean Energy Fund for Geopower demonstration project in Northern Canada, in partnership with the Acho Dene Koe First Nation community
  - **$2.6 Million** from the Alberta Energy Research Institute to support research on geothermal power in the Alberta Foothills
- This represents the first geothermal company in Canada to receive any significant government funding
- Financial support like this helps to "de-risk" the geothermal paradigm in Canada.

Canadian Policy

- EcoEnergy for Renewable Power incentive of $10/MWh
  - When this incentive was announced, it stated that ocean and geothermal energy would be evaluated on a case by case basis
  - Need to be on-line by 2011 (now fully subscribed)
  - Not indexed to inflation even though the program ends in 2021
  - Only for >1 MW (some of the demonstration sites or micro-opportunities will be excluded)
- No EcoEnergy for Renewable Heat incentive for Geothermal
  - There currently is an attractive 25% rebate for solar heat projects but none for geothermal Direct Use or industrial sized Heat Pumps

2010 Federal Budget

- No new funding for Geothermal Energy in 2010 Budget
- Canada has committed to providing 90% renewable electricity by 2020 but has failed to renew the EcoEnergy for Renewable Power program



2010 Budget Highlights:

- Accelerated Capital Cost Allowance for renewable power equipment
- Establishment of Canadian Renewable and Conservation Expenses, allowing for flow-through shares for investors

Geothermal Power Policy Forum

June 24th, 2010 – Ottawa, Ontario

- This inaugural event will bring together politicians and policy makers to address gaps in policy and research needed to advance geothermal energy in Canada
- Come network with some of Canada's leading authorities on renewable energy and sustainable development
- For registration details please visit www.CanGEA.ca

Be Inspired!

- CanGEA was founded in Spring, 2007
- Look at what we've done in 2.5 years as a mostly volunteer based association
- IMAGINE what we could do with your help

Join Us!

- With a united voice, we can achieve our goal

Accelerate Canadian exploration and development of geothermal resources in order to provide secure, clean and sustainable energy

CanGEA
CANADIAN GEOTHERMAL ENERGY ASSOCIATION

Thanks to Our Members!

BORDEN LADNER GERVAIS

Chevron

ENBRIDGE

TMX Toronto Stock Exchange | TSX Venture Exchange

magma ENERGY CORP

nexen

ORMAT

GRADIENT Geothermal

SUNCOR ENERGY

YUKON ENERGY

SOMERVILLE

ThermaSource
GEOTHERMAL CONSULTING AND DRILLING

Íslandsbanki
Specialists in Geothermal Financial Services

Savanna Drilling

BOREALIS GEOPOWER

Blakes LAWYERS

SGP

MANNVIT ENGINEERING

DUNDEE WEALTH MANAGEMENT
Dundee Securities Corporation

NGP NEVADA GEOTHERMAL POWER

MERIDIAN ENVIRONMENTAL

Ram Power, Inc.

MAINSTREAM RENEWABLE POWER

BEACON HEAD ENERGY LTD.

CLARK WILSON LLP
BC's Law Firm for Business

Ruinril Petroleum

WELLINGTON WEST

CALDERA GEOTHERMAL

GLACIER Partners

GeothermEx, Inc.

SKM

JACOBSECURITIESinc

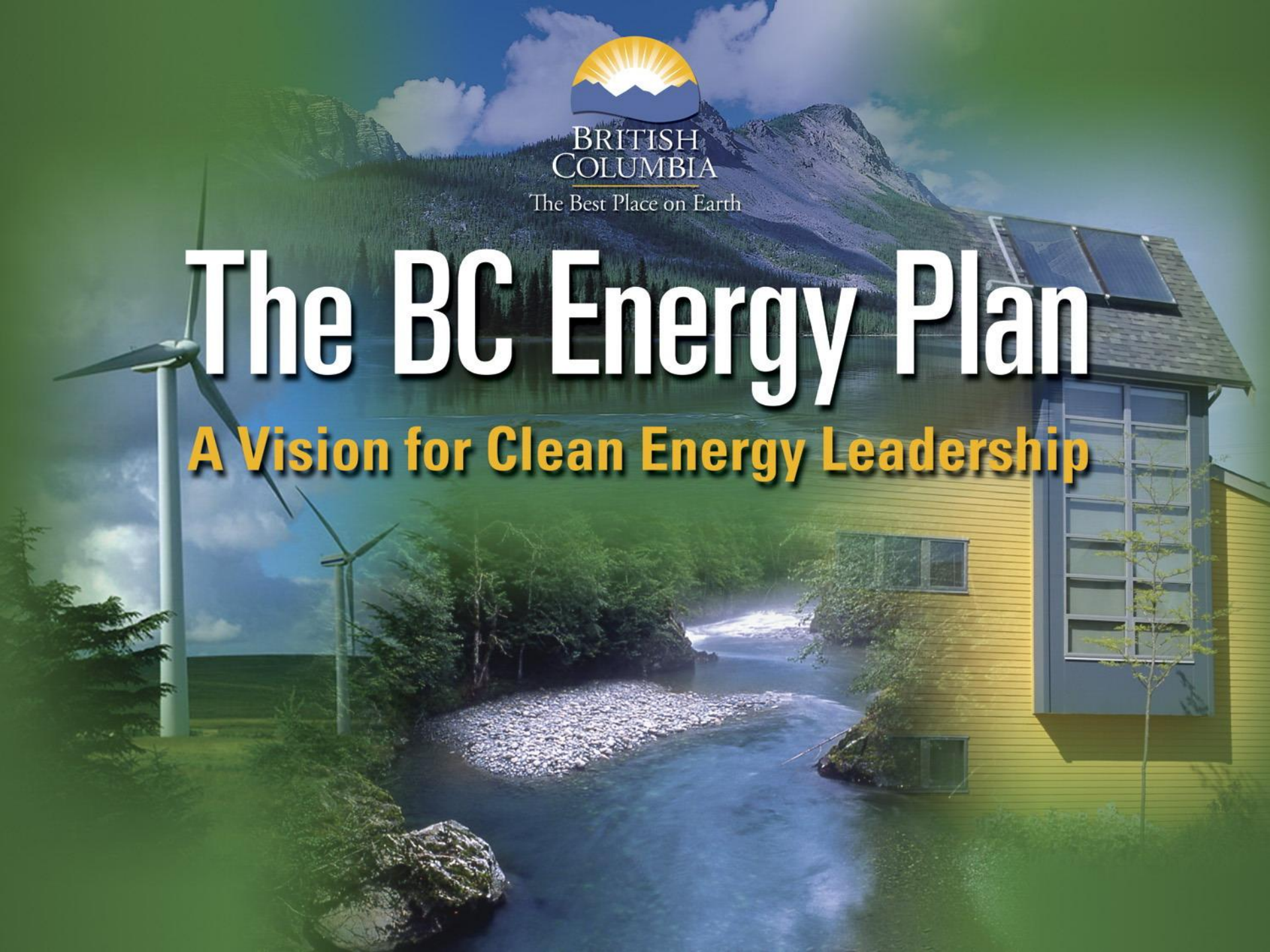
ADVANCING GEOTHERMAL ENERGY DEVELOPMENT IN BRITISH COLUMBIA

March 2010
Yukon Geophysical Workshop

Garth Thoroughgood
A/Director, Resource Policy and Planning
BCMEMPR

Presentation Overview

1. British Columbia – clean and renewable energy policy direction and priority
2. Resource Potential
3. Tenure History
4. Geothermal – legally defined
5. Geothermal Resources Act – overview
6. Regulations – overview

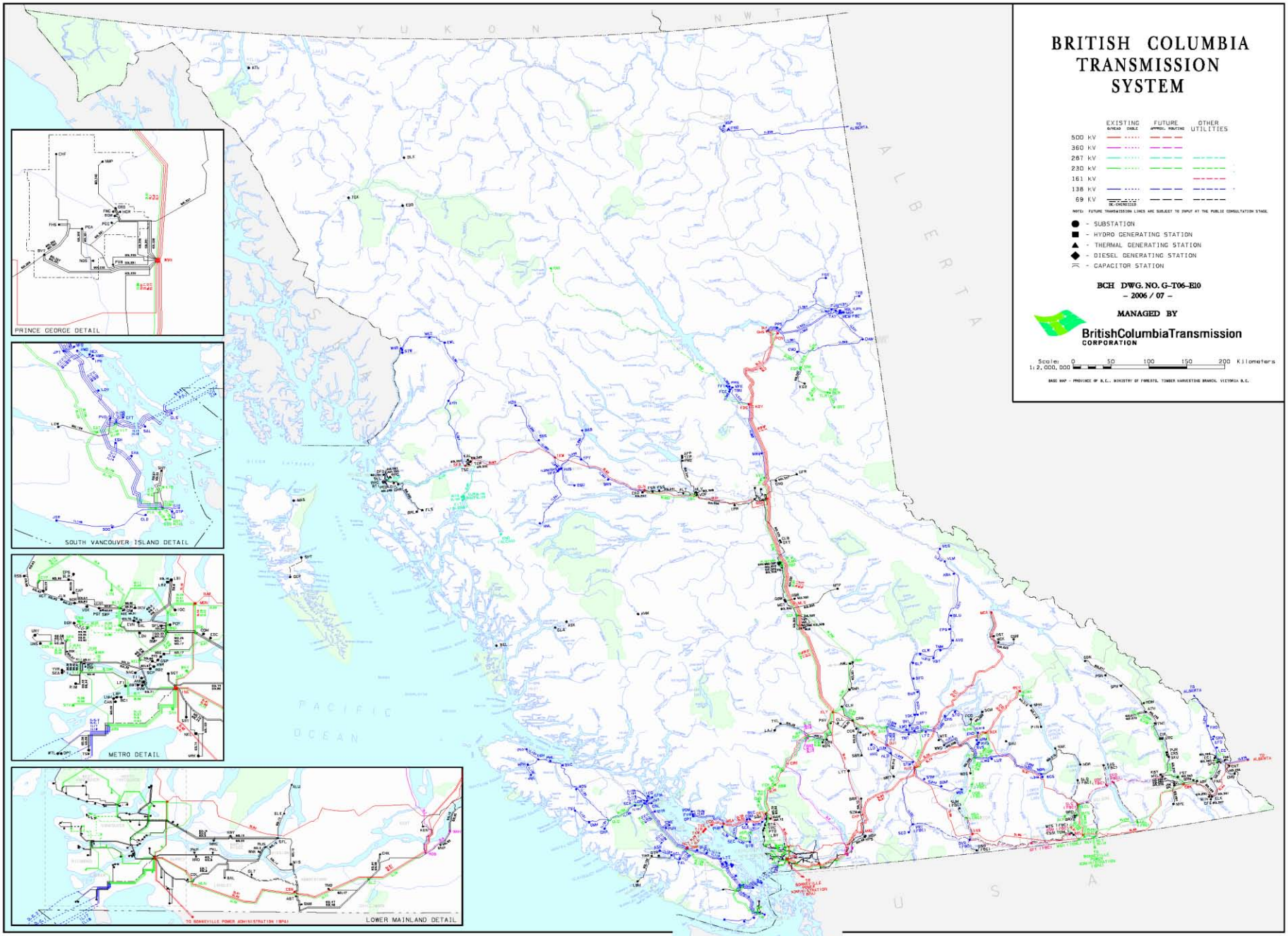

BRITISH
COLUMBIA
The Best Place on Earth
The BC Energy Plan
A Vision for Clean Energy Leadership

Speech from the Throne February 9, 2010
Recognizes that clean energy is a key part of BC's Climate Action Plan to reduce greenhouse gas emissions by 1/3 by 2020.

A Clean Energy Act will be created and will encourage new investment in independent power production while also strengthening BC Hydro.

It will provide fair, predictable, clean power calls and will feature simplified procurement protocols.

Throne Speech recognizes geothermal as one of our renewable energy's that has enormous potential


BRITISH COLUMBIA
TRANSMISSION
SYSTEM
EXISTING
OVERHEAD
CABLE
FUTURE
OVERHEAD
ROUTING
OTHER
UTILITIES
500 kV
360 kV
287 kV
230 kV
161 kV
138 kV
69 kV
NOTE: FUTURE TRANSMISSION LINES ARE SUBJECT TO INPUT AT THE PUBLIC CONSULTATION STAGE.
- SUBSTATION
- HYDRO GENERATING STATION
- THERMAL GENERATING STATION
- DIESEL GENERATING STATION
- CAPACITOR STATION
BCH DWG. NO. G-T06-E10
– 2006 / 07 –
MANAGED BY
BritishColumbiaTransmission
CORPORATION
Scale: 1:2,000,000
0 50 100 150 200 Kilometers
BASE MAP – PROVINCE OF B.C., MINISTRY OF FORESTS, TIMBER HARVESTING BRANCH, VICTORIA B.C.
PRINCE GEORGE DETAIL
SOUTH VANCOUVER ISLAND DETAIL
METRO DETAIL
LOWER MAINLAND DETAIL
TO BONNEVILLE POWER ADMINISTRATION (BPA)
YUKON
N.W.T.
ALBERTA
PACIFIC OCEAN
U.S.A.

RESOURCE POTENTIAL

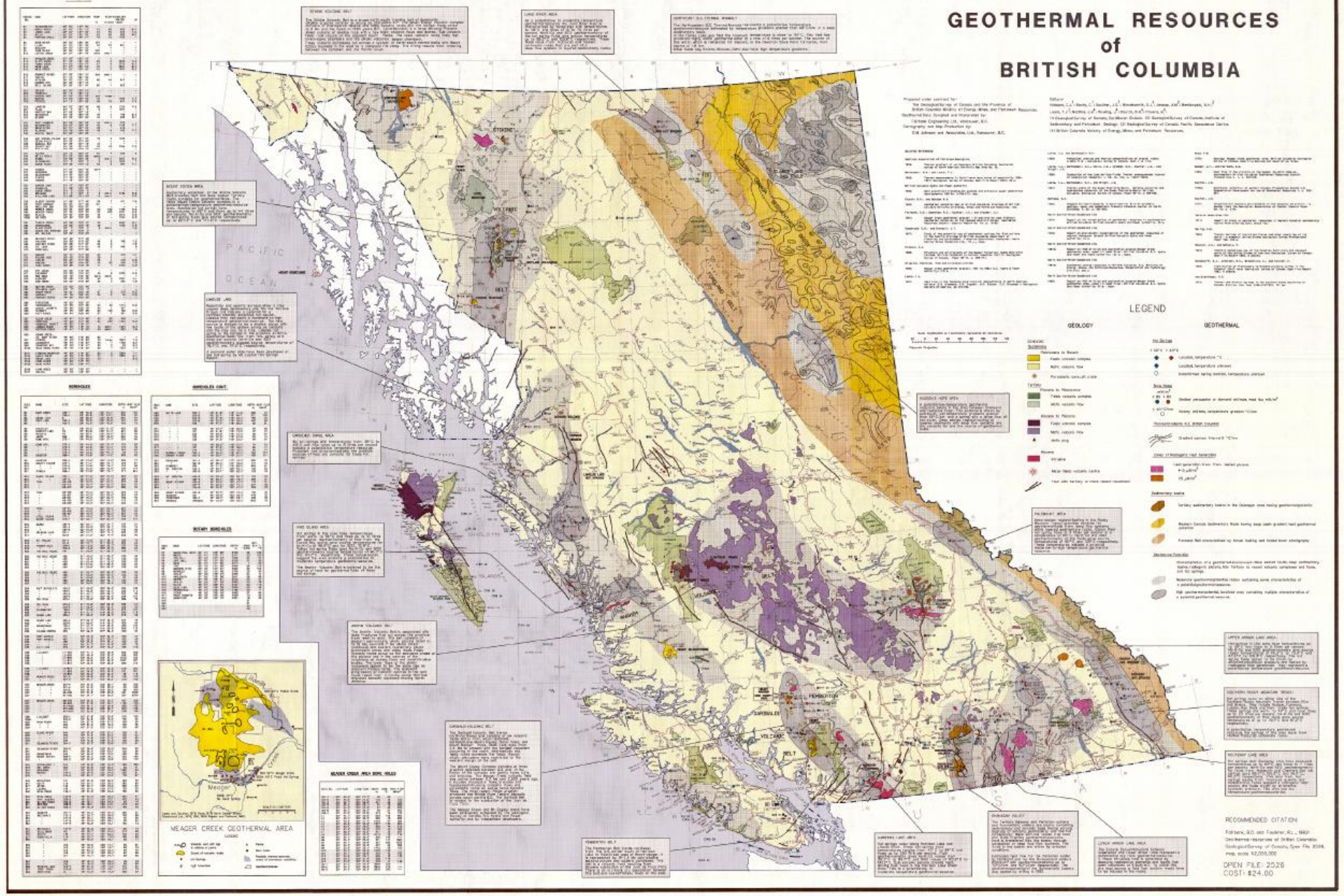
- Further exploration is required to assess viability. Will help to assess distribution and quality of the resource

- Areas around volcanoes and hot springs are of most interest to developers

- Some reports indicate potential for 1,000 MW to 5,000MW potential in British Columbia

Energy, Mines and Resources Canada
Province of British Columbia Ministry of Energy, Mines and Petroleum Resources
Geological Survey of Canada
Commission géologique du Canada
Canada

GEOTHERMAL RESOURCES of BRITISH COLUMBIA



TENURE HISTORY

- Existing tenure is limited.

- *Geothermal Resources Act* (GRA) was written in 1982 with minor amendments in 1996

- One Lease in existence is at Meager Creek – approx. 160km NW of Vancouver

- BC Hydro conducted a program of geothermal reconnaissance and general research that started in the 70's

BRITISH COLUMBIA

TENURE HISTORY CONT'd

•Reconnaissance was focussed on SW BC and eventually narrowed to the Meager Creek area

•An initial discovery well was drilled and found temps of 202 degrees C at fairly shallow depth

•Three deep exploratory wells were drilled in the early '80's which enhanced the knowledge of the area

•The program eventually saw a 20KW single flash turbine installed and Canada and BC had its first geothermal electricity production

BRITISH COLUMBIA

TENURING HISTORY CONT'd

- In 1983 the program was cancelled as part of a substantial capital cutback by BC Hydro

- In 1987 the first geothermal Lease under the GRA was issued by Order In Council

Meager Creek well pad

Meager Creek well pad

CURRENT BC TENURE

- Currently there are two geothermal permits in British Columbia

- Pebble Creek (northeast of Meager Creek)
  - One was issued in 2004

- Valemount and the Mica Creek Dam
  - Issued in 2004

- Exploration activities have been limited to date.

Geothermal Legally Defined

The right, title and interest in all geothermal resources in BC are vested in and reserved to the government.

Geothermal Legally Defined

The *Geothermal Resources Act* defines a geothermal resources as: “the natural heat of the earth and all substances that derive an added value from it, including steam, water and water vapour heated by the natural heat of the earth and all substances dissolved in the steam, water or water vapour obtained from a well, but does not include:

a) water that has a temp less than 80 degrees C at the point where it reaches the surface, or

b) hydrocarbons

BC Geothermal Resources Act (RSBC 1996)
Provides the framework for issuing, administering and regulating British Columbia's subsurface geothermal resources.

Forms of Tenure
Permits
- Cannot be issued except by public tender
- Exploration form of tenure
- Maximum size
- Must be renewed annually – maximum renewal is 7 times
- Annual rent and work requirements

Forms of Tenure cont'd

Leases

- Production form of tenure
- Permits must be converted to a Lease
- Leases have annual rent requirements but no annual work requirements
- Lease term is 20 years

Regulations
Geothermal Resources Administrative Regulation

•Outlines how Well Authorizations are to be applied for and received
•Provides information on fees for applications, permit renewals, rents, work requirements and other miscellaneous fees

Permits
•Must be renewed annually (meeting requirements)
•Can be renewed seven times (8 year total permit life)

Regulations cont'd

Leases

- Cannot be issued except to a person who holds a permit

- Leases are good for 20 years

- Annual rent and renewal fees are required

- Permits must have a geothermal well drilled on them and the Ministry must receive an acceptable development plan prior to converting it to a Lease

Geophysical Exploration Regulation

•Outlines requirements for geophysical exploration including seismic surveys

•Ministry uses the geophysical regulation under the *Petroleum and Natural Gas Act*

Geothermal Drilling and Production Regulation

•Provides technical information on regulatory environment for geothermal well drilling and production of a geothermal resource

•Is being re-written by the Oil and Gas Commission as part of consequential amendment process

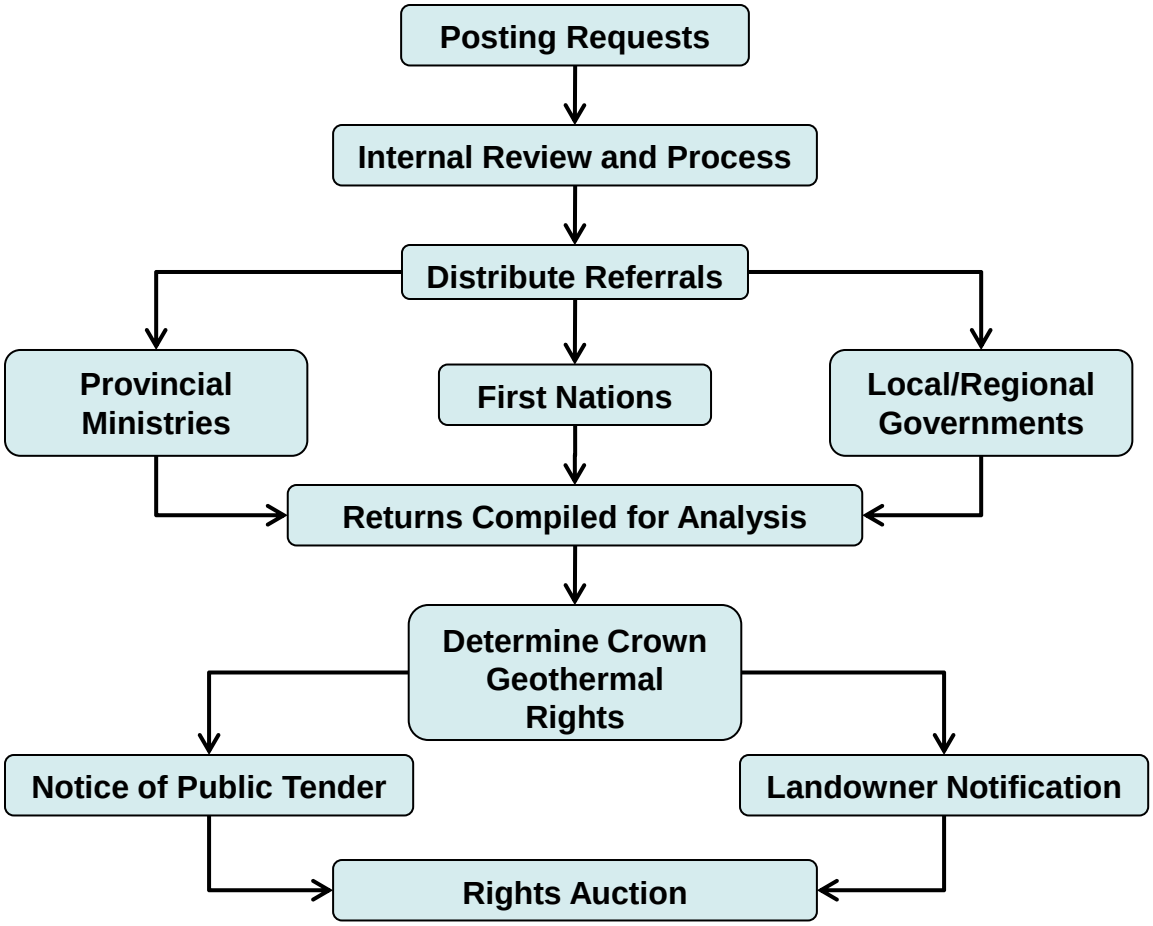
Consequential Amendments to the *Geothermal Resources Act*

- *Oil and Gas Activities Act* sets out consequential amendments to the *Geothermal Resources Act*
- Main focus of the amendments is to transfer the regulatory authority of geothermal exploration and development to the BC Oil and Gas Commission

Advancing Geothermal Development in BC

- 2008 Ministry established a Geothermal Task Force
  - Workshops and consultation with industry
- 2009 Referral process starts for four initial areas
- Operational Policy creation for surface land tenure
- Tenure disposition for Knight Inlet – March 29th
- Notice to be posted for new tenure requests

Tenure Referral and Auction Process



Next Steps

-Advancing disposition of tenure
    -March 29, 2010 – disposition of Knight Inlet
-Reviewing legislation/regulations
-Policy working group with CanGEA
    -Main focus on amendments to *legislation* and regs
    -Will review other potential policy initiatives
-Accepting new tenure requests from industry

Summary

B.C. is moving towards making more geothermal subsurface rights available for public tender.

We are excited about the potential benefits geothermal can offer as an alternative energy source and B.C. has the potential to be a leader in this clean, green technology.

QUESTIONS?

http://www.empr.gov.bc.ca/Titles/OGTitles/geothermal/Pages/default.aspx

Contact
Garth Thoroughgood
(250)952-6382
Garth.Thoroughgood@gov.bc.ca

Energy Strategy for Yukon

March 2010

Energy Strategy Highlights

- Released in January 2009
- Yukon's first comprehensive energy strategy
- A vision for conserving, using and developing Yukon's energy resources
- Commits to 24 priority actions

Energy Strategy Priorities

- Yukon government's energy priorities:
  - Conserving energy and using it more efficiently
  - Increasing renewable energy
  - Meeting Yukon's current and future electricity needs
  - Managing responsible oil and gas development

Efficiency and Conservation

- Increase efficiency by 20% by 2020
- Energy efficient buildings:
  - Energy auditing training courses
  - Home repair financial assistance
  - Building SuperGreen and Near Zero homes
- Good Energy program provides rebates for energy efficient products

Renewable Energy

- Increase renewable energy supply by 20% by 2020
- Renewable energy pilot projects:
  - District heating (Watson Lake, Whitehorse)
  - Waste heat from diesel (Old Crow)
  - Solar panels and wood heating systems for institutional buildings
- Wind monitoring service coming soon

Electricity

- Funding for infrastructure projects:
  - Extend the grid from Pelly Crossing to Stewart Crossing
  - Upgrade Mayo dam, Mayo B
  - Third turbine at the Aishihik dam
- New policy to facilitate independent power production and net metering
- Demand management programs

Oil and Gas

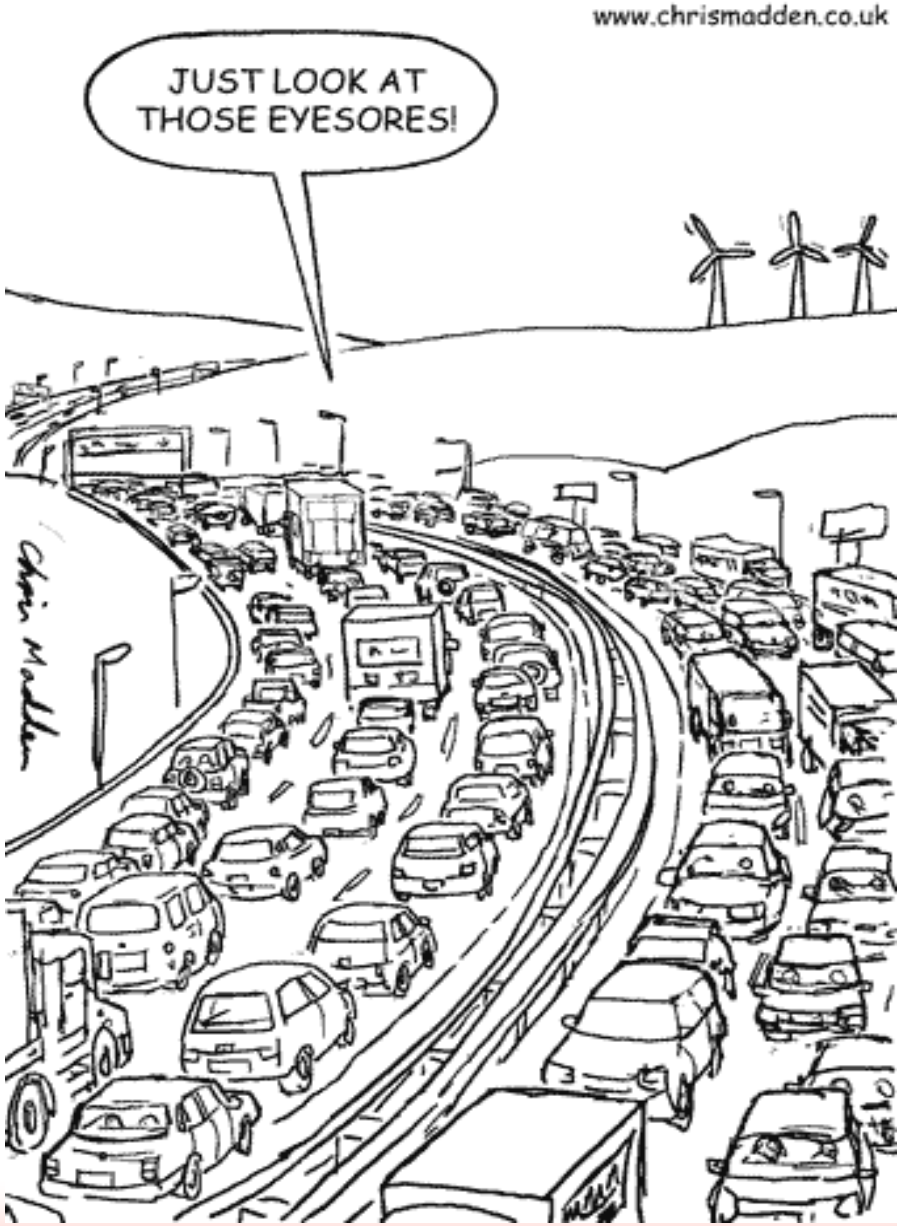
- New pipeline regulations
- Best practices for the oil and gas sector:
  - Caribou, trappers and wetlands (new)
  - Seismic (updated)
  - Minimize greenhouse gas emissions
- Prepare for the Alaska Highway Pipeline
- Interim agreement with Canada for offshore oil and gas resources

Geothermal Energy

- Develop a policy framework for geothermal energy
- Consider geothermal opportunities for heating and electricity
- Support for renewable energy pilot studies and projects, including geothermal

Implementation

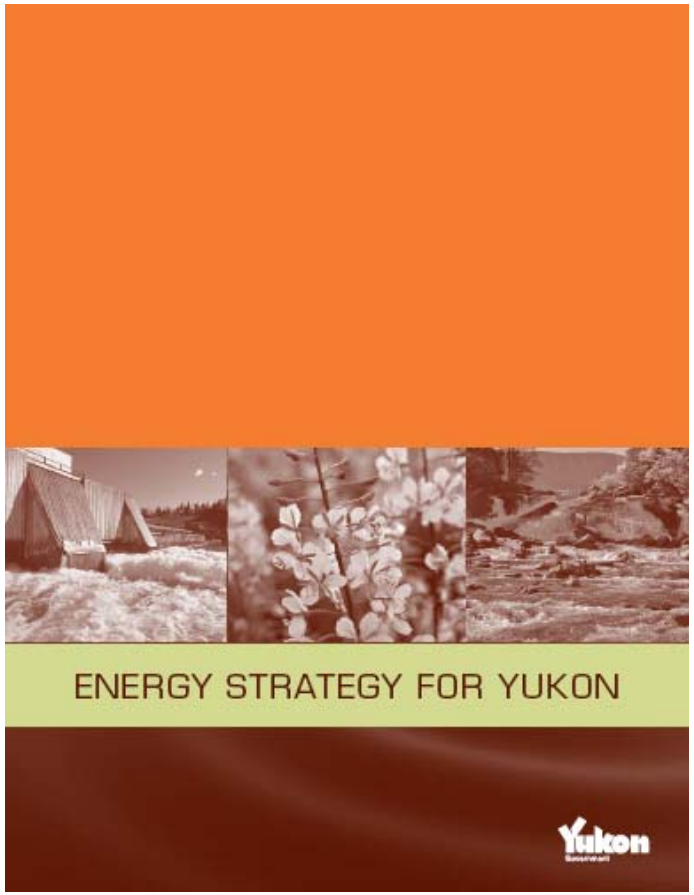
- Strategy set the overall direction
- Detailed policies and programs
- Policy analysis
- Public opinion
- Reporting back

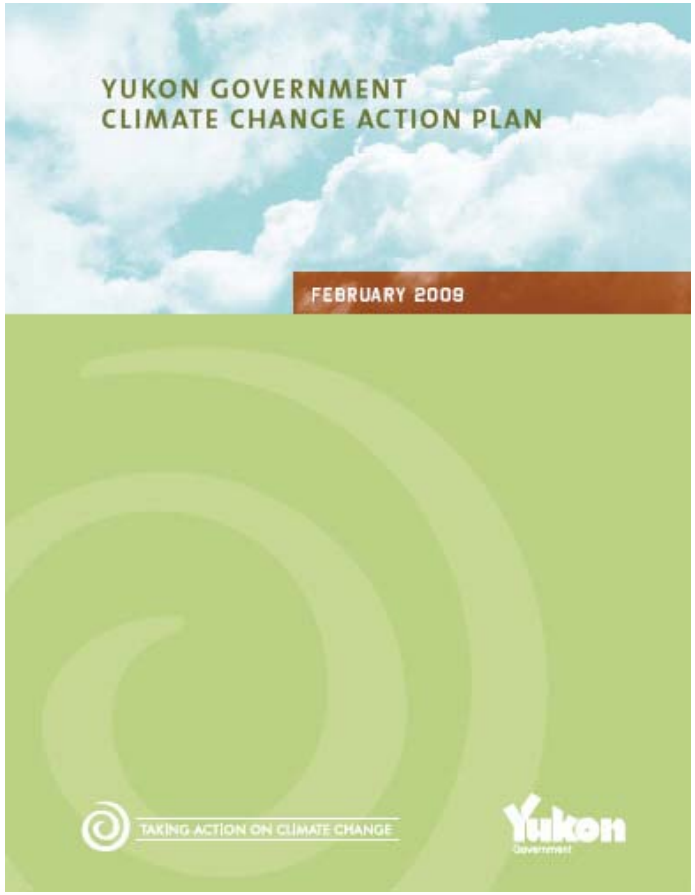


Reporting on Progress

- Energy Strategy commitments:
  - Monitor implementation
  - Track status of the priority actions
  - Report regularly on progress
  - Release the first progress report by the end of 2010

Energy and Climate Change





Climate Change Action Plan

- Coordinated approach
  - EMR and Environment
  - Interdepartmental technical working group
  - New Climate Change Secretariat
- Shared priority actions
  - Green procurement policy for government
  - Energy efficient transportation study
  - Environmental stewardship in the schools

Next Steps

- Implementing the strategy is a priority for the government
- Following through on the commitments
  - Allocate sufficient resources
  - Implement the priority actions
  - Monitor and report on progress
- Any questions or comments?
- Email energystrategy@gov.yk.ca

consulting engineers
& scientists

YEC Geothermal Exploration Program
Yukon Territory

Yukon Energy Corporation
David Morrison, President and CEO, Hector Campbell, Director

EBA Engineering Consultants Ltd.
Stephan Klump, Ph.D., Jack Dennett, P.Geo.

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Overview

- Phased Approach to Geothermal Exploration / Development
- Geothermal Exploration Methods
- Case Study: Jarvis River Warm Springs, SW Yukon
- Outlook

Phased Approach to Geothermal Exploration

1. **Reconnaissance Studies (3%)** - Regional (1,000s km^2); synthesize geoscience info, preliminary geological mapping, geochemical sampling, API, remote sensing; initial conceptual models

2. **Pre-Feasibility Studies (3%)** – More focused (100s km^2); surface exploration for subsurface structure, detailed mapping, low-level TIR flying; surface geophysics (i.e., gravity, magnetic, resistivity, seismic); advanced geochemistry; thermal gradient holes (DDH) with core logging; environmental assessment and permitting considerations

3. **Feasibility and Resource Confirmation (5%)** – Deep drilling/logging of geothermal reservoir to support/refine geothermal model; quantitative assessments of resource; detailed geochem analysis of fluids; initiate formal environmental assessment process; secure financing for geothermal development

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Phased Approach to Geothermal Exploration

4. **Geothermal Resource Development (31%)** – Activities to bring field to production; complete environ assessment process; final legal/regulatory permits/land arrangements; production & injection wells drilled, tested, completed; surface piping/fluid handling system designed & constructed (may be significant cost)

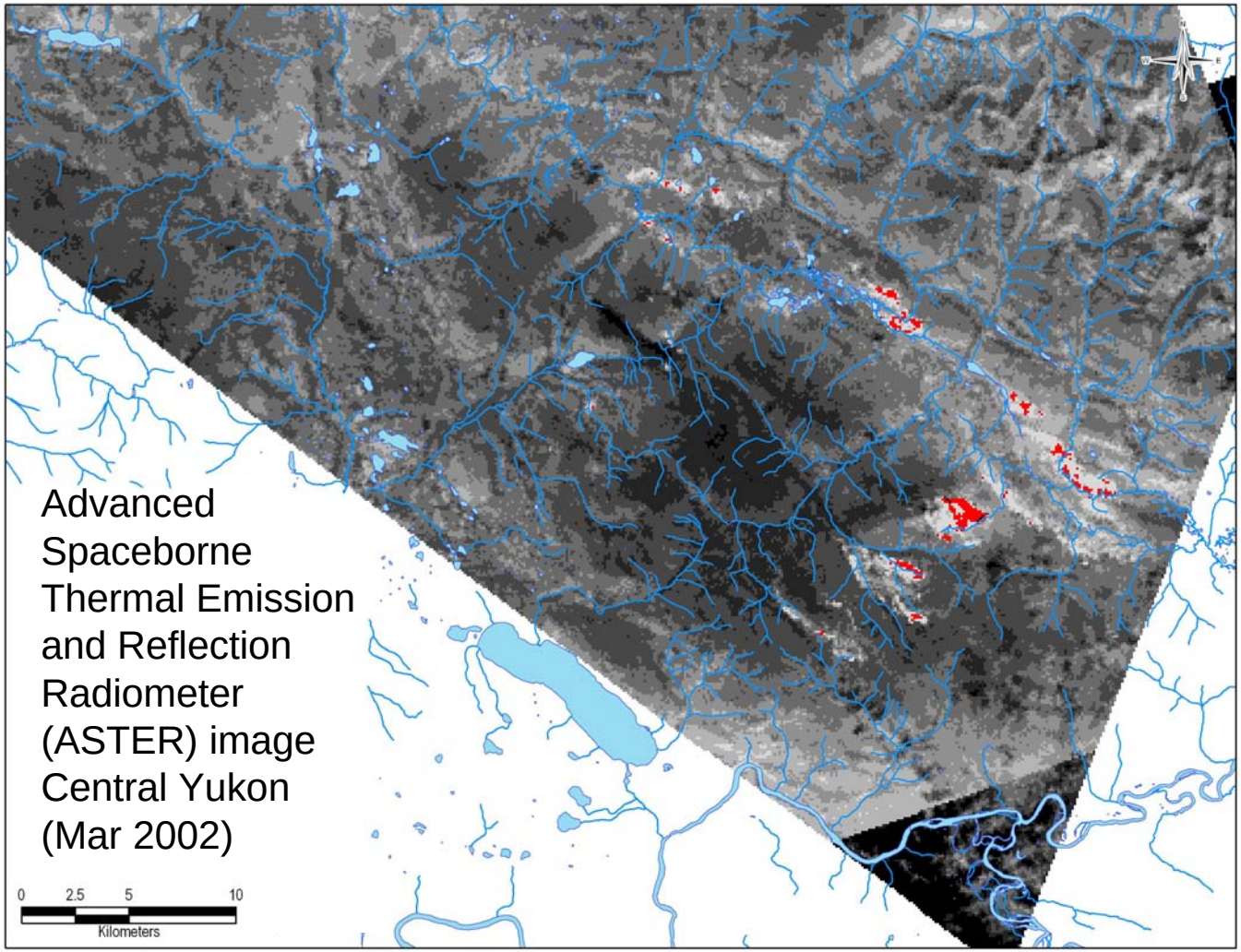
5. **Power Plant Installation & Commissioning (58%)** – Activities to bring power plant on line to supply electricity; plant designed & constructed; transmission lines and supporting infrastructure designed & constructed

Budget % breakdown from GEA 2005

Typical all-in costs ~$4-5M/MW (USA), likely more in remote Yukon

Methods – Satellite Imagery

- LANDSAT night & day scenes, Mar & Sep, images 180 km x 180 km; 60 m pixels
- ASTER night & day scenes, multiple thermal/ spectral wave-lengths; 60 km x 60 km, 90 m pixels



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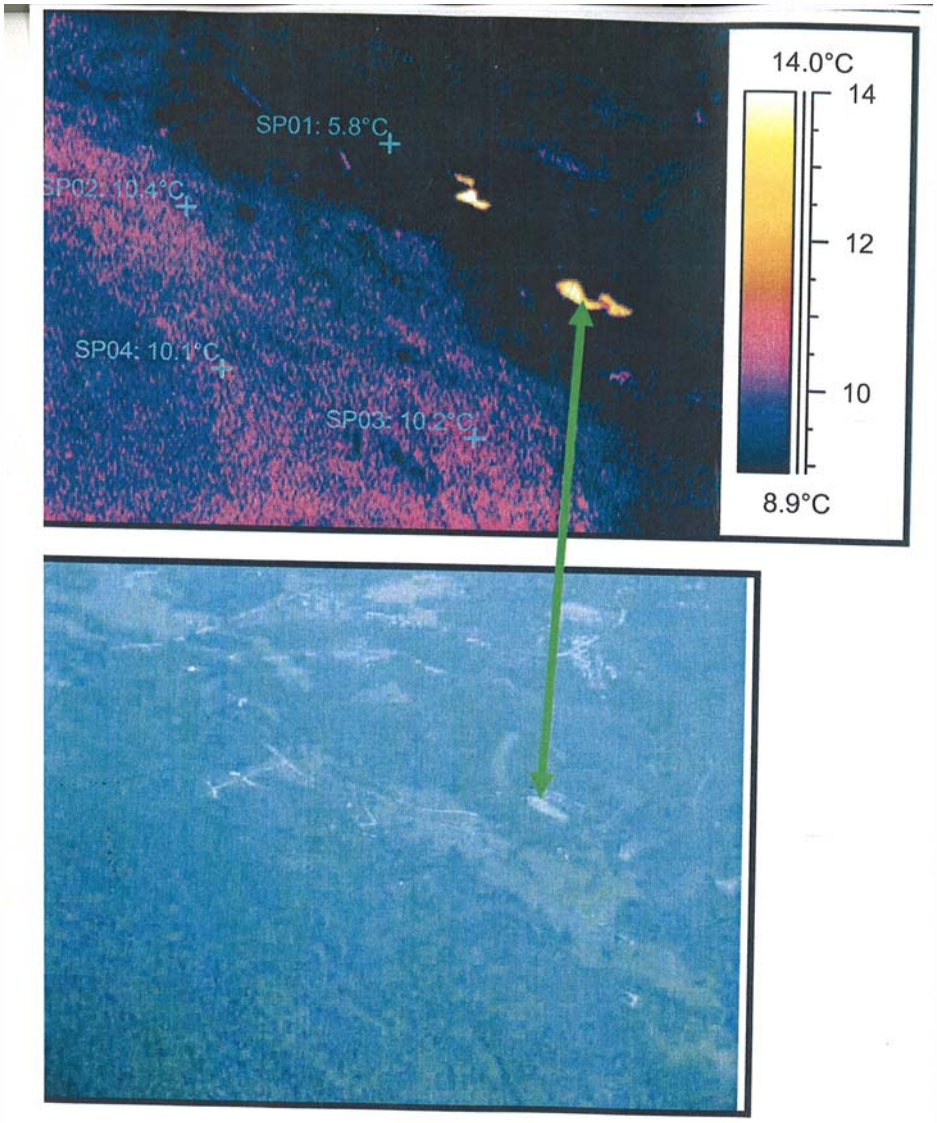
Methods – Low-level TIR Survey

- Using radiometric handheld infrared camera (Agema 550) from helicopter platform
- Optical and thermal videos of transects with GPS waypoints
- Early dawn flying to avoid solar thermal interference



Example image from SE BC, Spectrum Infrared Ltd.

Methods – Visual Open Water Surveys

- Altitude 1,000 feet; 100 km/hr airspeed; 2 observers;
- Warm water shows up well against snow;
- Relatively low-cost survey of large areas.

Cessna 180

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Methods – Visual Open Water Surveys

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Methods – Visual Open Water Surveys

Methods – Ground Reconnaissance

- Geological mapping;
- Document surface features;
- Water sampling and flow estimates; and,
- Temperature and other field parameter measurements.

Hot spring, Central Yukon

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Methods – Water Analysis

- Field: pH, temperature, electrical conductivity;
- Lab: alkalinity (total, HCO_3, CO_3, OH), hardness, F, Cl, NO_2, NO_3, SO_4, dissolved metals, environmental isotopes (^{18}O, ^{2}H);
- Metals field-filtered, acidified;
- Si diluted 10x with DW.

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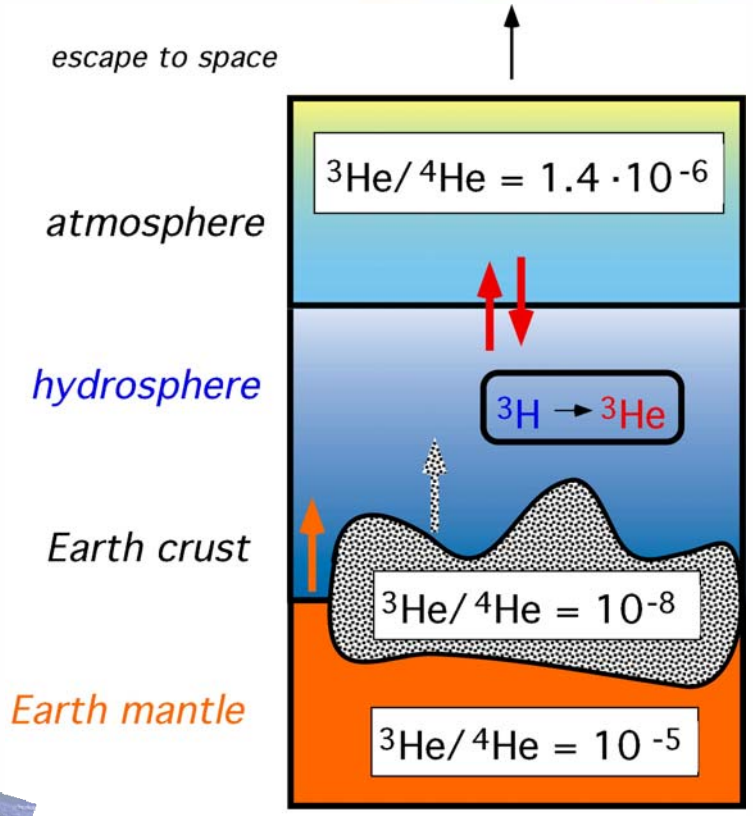
Innovative Approach

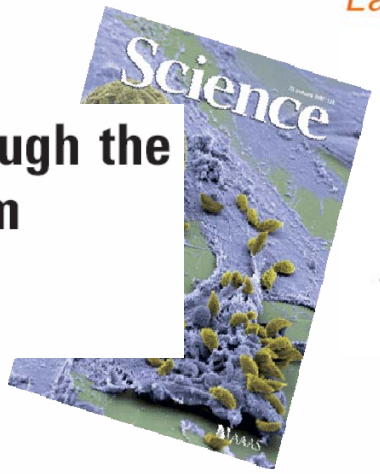
- EBA/YEC collaboration with Swiss university (ETH Zurich);
- High helium isotope ratio can be indicative of deep fluid circulation;
- ^{4}He can be used as a (qualitative) tracer of 'groundwater age'.



Flow of Mantle Fluids Through the Ductile Lower Crust: Helium Isotope Trends

B. Mack Kennedy[1] and Matthijs C. van Soest[2]

Science, November 2007

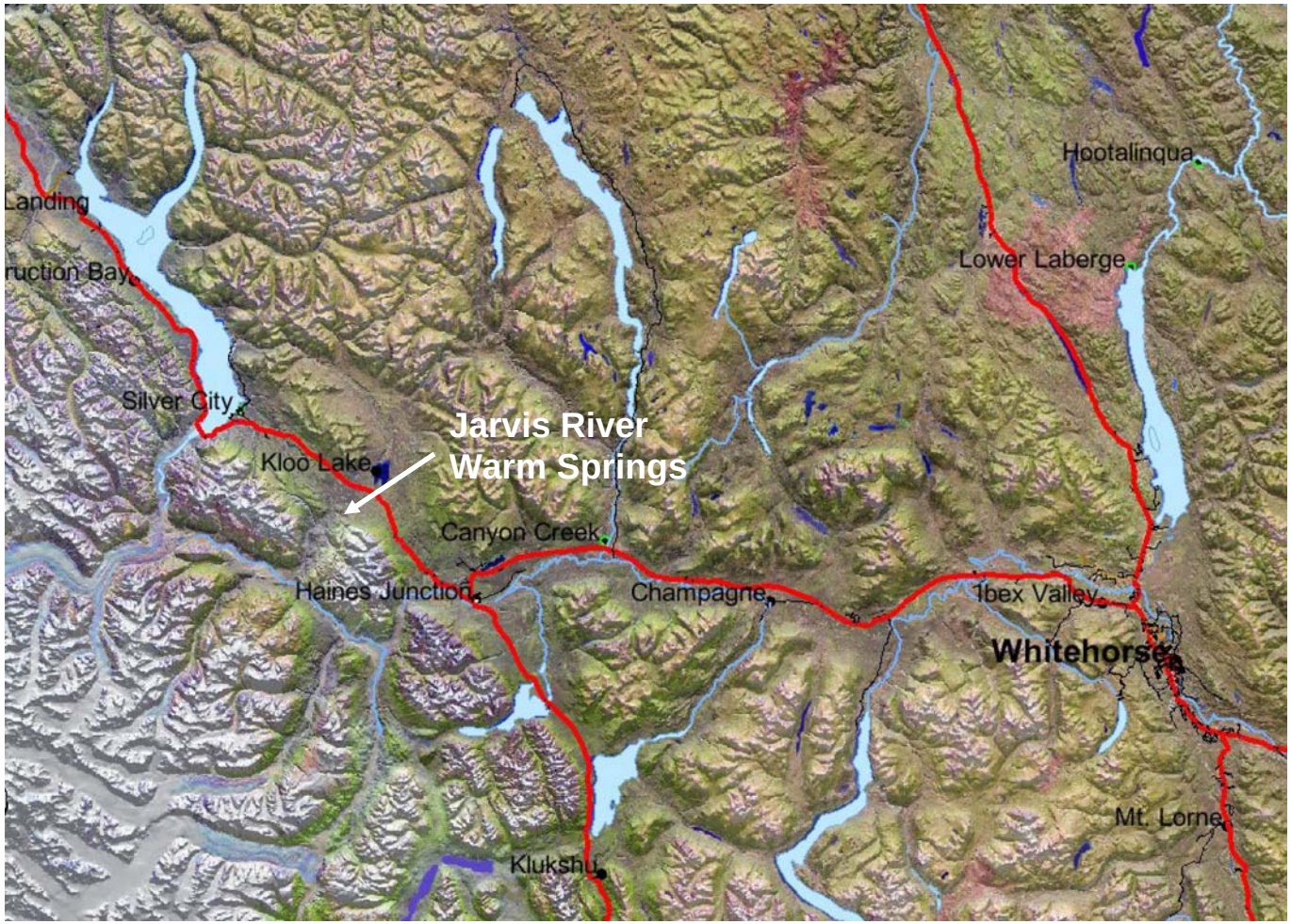


^{3}He: Earth formation (Big Bang)
decay of ^{3}H

^{4}He: decay of U, Th
Earth formation

Case Study

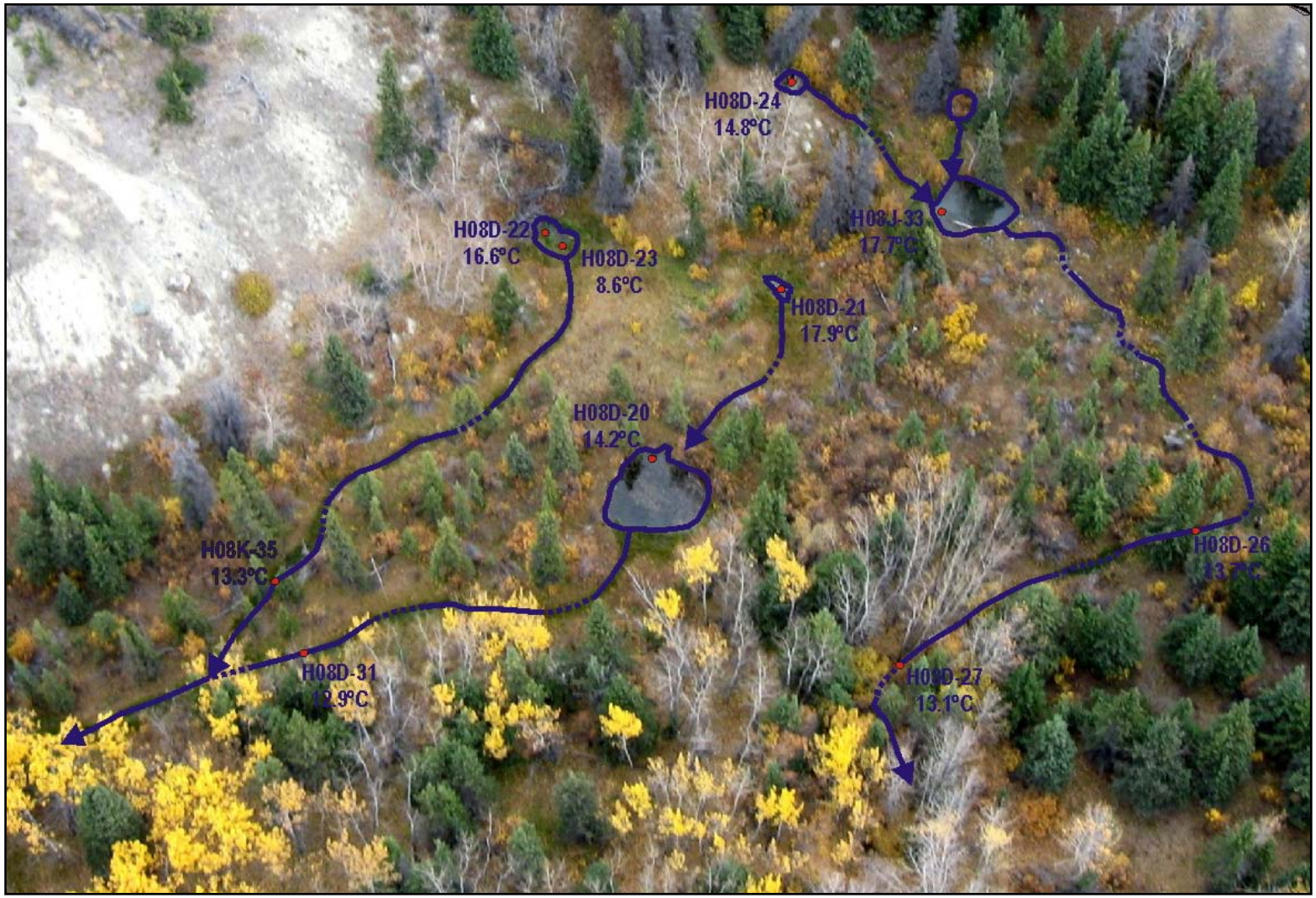
Jarvis River Warm Springs, SW Yukon



Reconnaissance Study

- Non-intrusive ground work, including regional surface water temperature survey and measurement of chemical field parameters;
- Preliminary geological mapping;
- Chemical analysis of selected spring water samples;
- Geothermometry;
- Development of preliminary conceptual geothermal model for Jarvis River Warm Springs.

Spring water temperatures



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Results of Reconnaissance Study

- Jarvis River Warm Springs consist of about six shallow pools with a maximum water temperature of about 18°C;
- Spring water shows characteristic chemical composition (sodium-bicarbonate water type) that is different from other surface water in the area;
- Geothermometer methods suggest maximum subsurface water temperatures in the order of about 100°C;
- Geological setting of warm springs is difficult to assess because of the lack of bedrock outcrops in the area of the springs.

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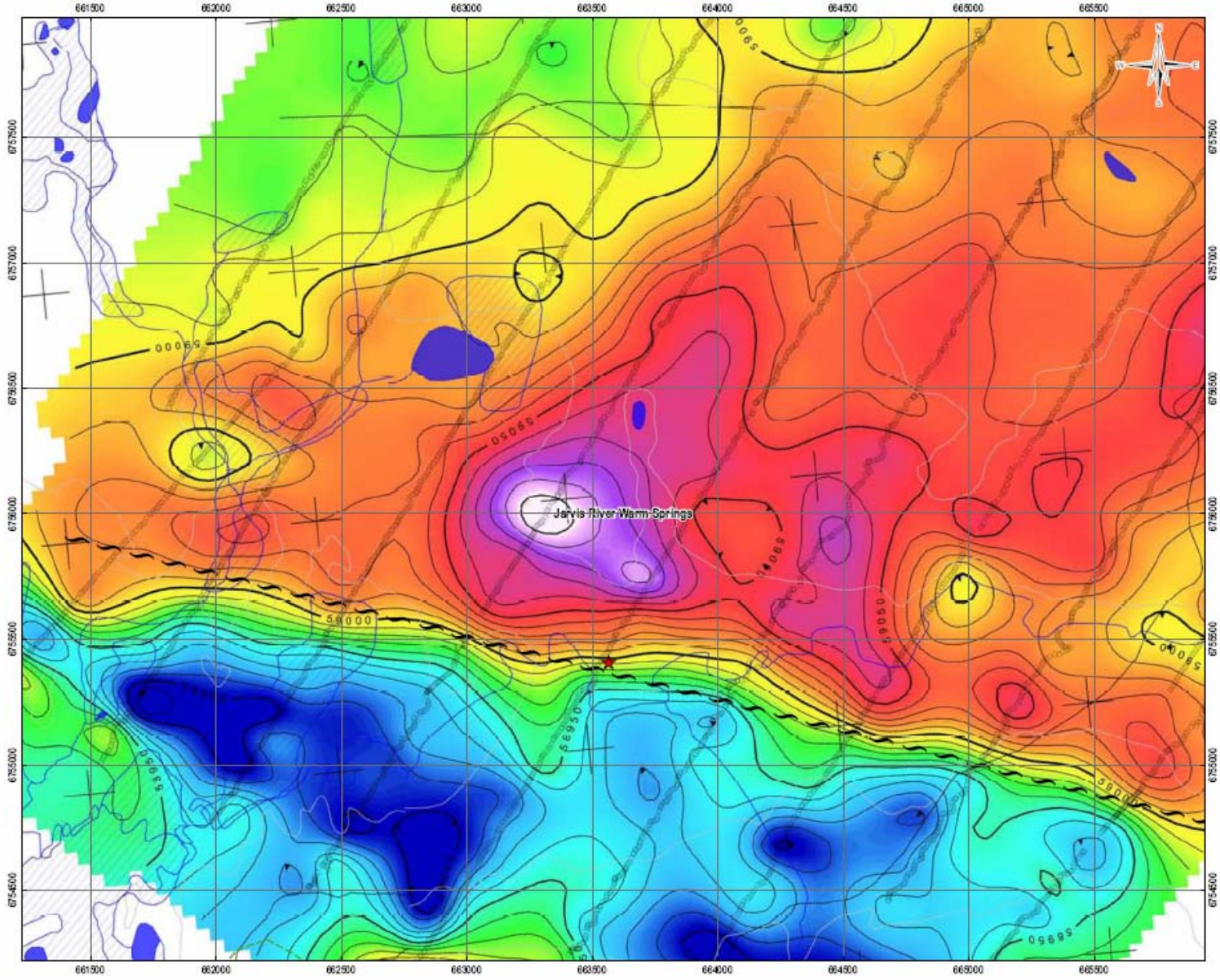
Advanced Exploration

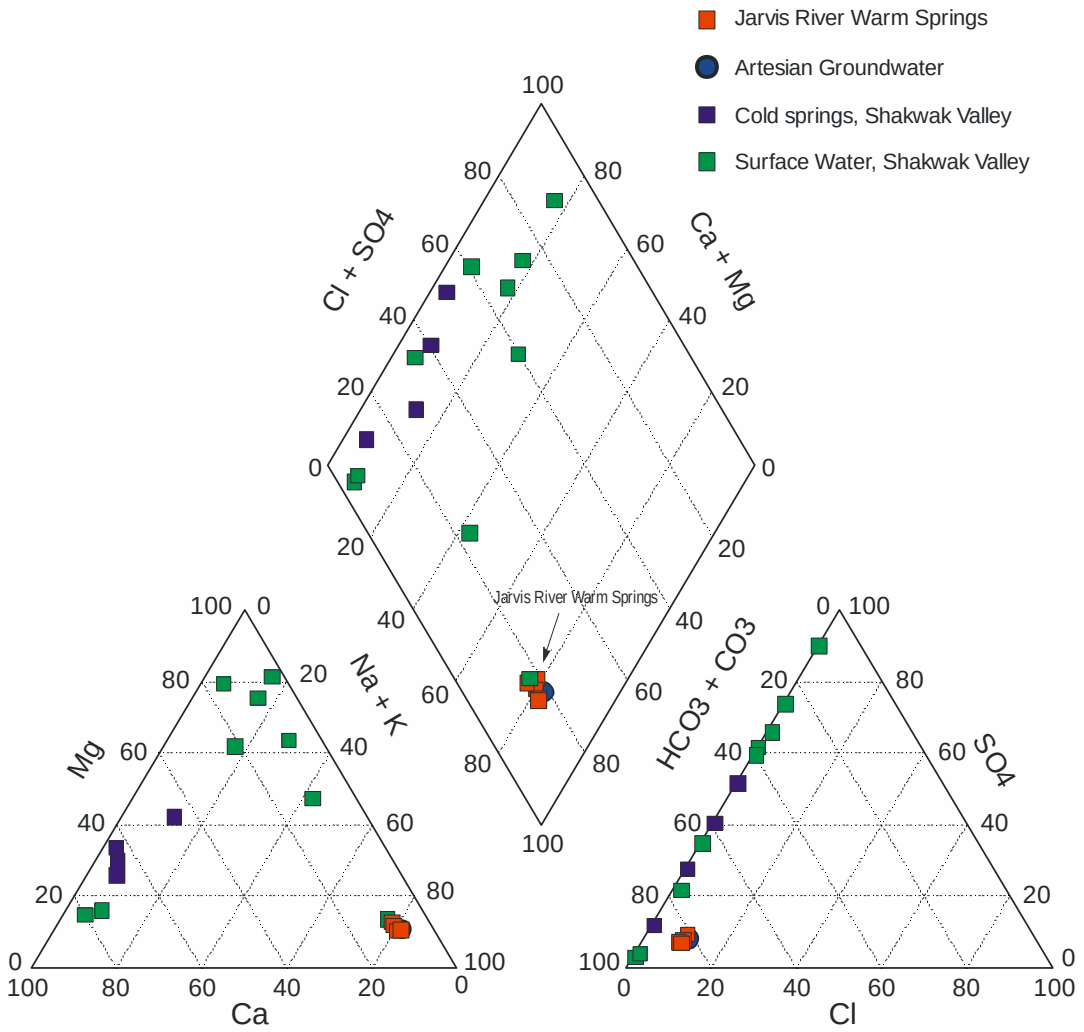
- Winter open water survey;
- Geophysical survey;
- Detailed geological mapping;
- Advanced geochemistry including dating of thermal water;
- Geothermometry; and,
- Exploration drill hole.

Geophysical Survey (TMF)



Hydrogeochemistry

- JRWS show distinct geochemical signature (sodium-bicarbonate)
- Sample from artesian aquifer is chemically identical to samples collected from warm spring pools



Geothermometry

TABLE 1: GEOTHERMOMETER RESULTS FOR JARVIS RIVER WARM SPRINGS				
Sample	Na-K-Ca	Na-K	SiO_2	SiO_2
	°C			
H09S-1	70	71	78	78
H09S-2	81	82	79	78
H09S-3	68	62	75	74
H09S-4	62	53	73	73
H09S-19	71	60	76	76
JR09-01-1	77	69	75	74
JR09-01-2	77	69	75	75
Mean Temperature	**72**	**67**	**76**	**75**

Water Dating

- Tritium concentration below detection limit
  - Residence time >50 years
  - No significant admixture of young, shallow groundwater

- Radiocarbon concentration was very low (2.24 pmc)
  - Conventional radiocarbon age is ~30,000 years
  - No significant admixture of young, shallow groundwater

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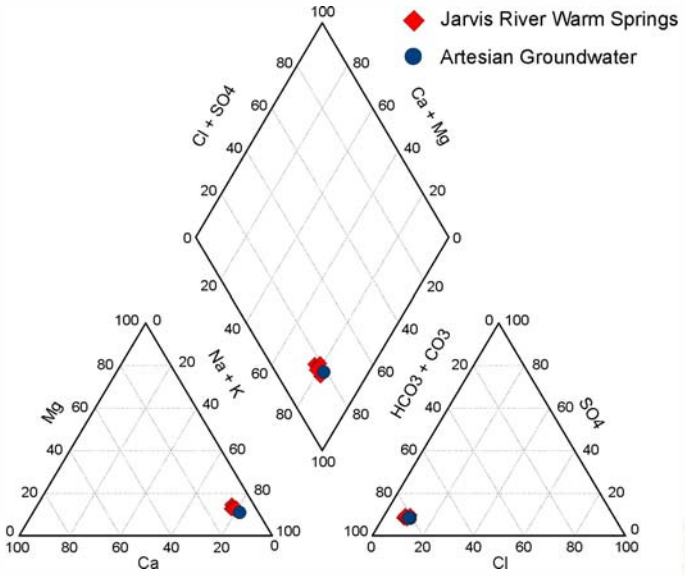
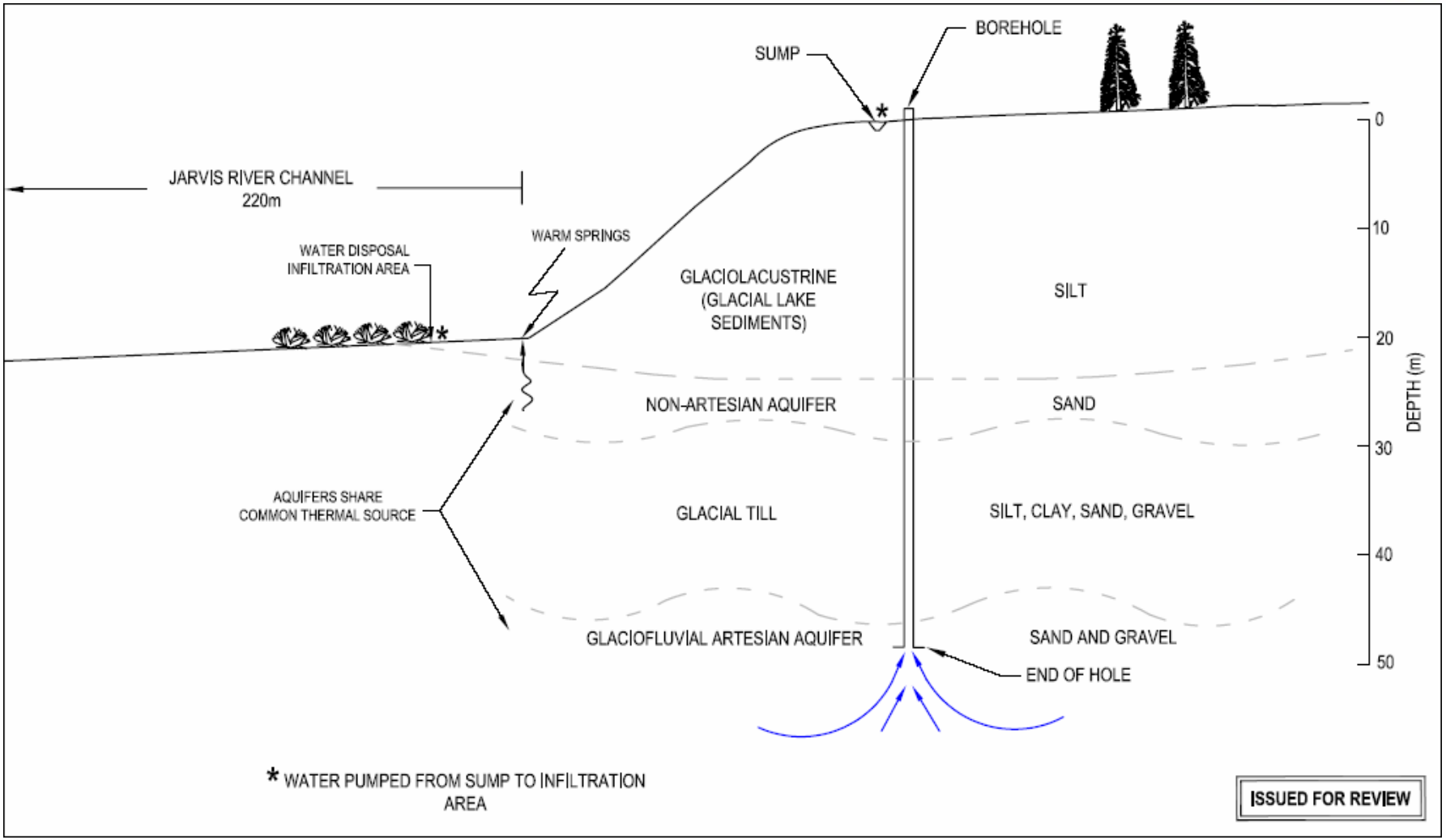
Drilling - Preliminary Results

- Overburden thickness is greater than 50 m;
- Warm springs are not directly related to fracture in bedrock;
- Strongly artesian aquifer exists within overburden sediments starting at about 50 m depth;
- Chemical composition indicates that artesian aquifer is source of warm springs.



Cross Section



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Outlook

- On-going geothermal exploration program;
- Focus on prospective sites near existing power grid;
- Advanced exploration including detailed geology, geophysics, and geothermal gradient holes;
- Goal: Advance suitable sites to Phase 3: Feasibility and Resource Confirmation.

YUKON ENERGY

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Yukon Cold Climate Innovation Centre

Energy Innovations for the North

Chad P. Gubala, Ph.D.

Yukon College and Yukon Economic Development

Cold Climate Innovation Centre

Foster Technology, Business and Academic Advancement through Applied Research and Development

Increase the Reliability of Yukon/Canadian Economy and Infrastructure

Expand the Knowledge Based Economy

Yukon Cold Climate Innovation Centre

YukonCollege

Yukon Government

Rationale

Science Technology and Innovation Council National Directive

thestar.com

Innovate or perish, Canada warned

We have the knowledge, but aren't converting it to wealth, experts say

May 05, 2009

BRUCE CAMPION-SMITH
OTTAWA BUREAU CHIEF

OTTAWA – Canada needs to step up efforts in science, technology and innovation or risk being left behind in the global race for talent and wealth, a blue-ribbon panel of academics, business leaders and government officials will warn today.

The Science, Technology and Innovation Council, formed in 2007 to advise the federal government on science and technology, is expected to issue mixed grades on the state of innovation in Canada.

Despite a "strong science base and a robust research capacity," new discoveries are not being "sufficiently" turned into commercial products and services. That means Canada is missing opportunities to "make a difference in people's lives and turn knowledge into wealth."

Yukon Cold Climate Innovation Centre

YukonCollege

Yukon Government

Science and Innovation National Priorities

www.stic-csti.ca

Environment

Natural Resources and Energy

Information and Communications Technologies

Health and Life Sciences

Yukon Cold Climate Innovation Centre

YCCIC Programs in Progress:

- Stirling Engine Program
- Transportation R+D – Permafrost and BST Surfaces
- Hydro-kinetic Energy (HKE) Generation Program
- ICT and Sensor Development and Integration

Planned:

- Cold climate food storage technologies and Dietary Health.
- Northern smart home technologies.
- Cold climate bio-remediation technologies for metal effluent abatement.
- Geothermal and alternate energy

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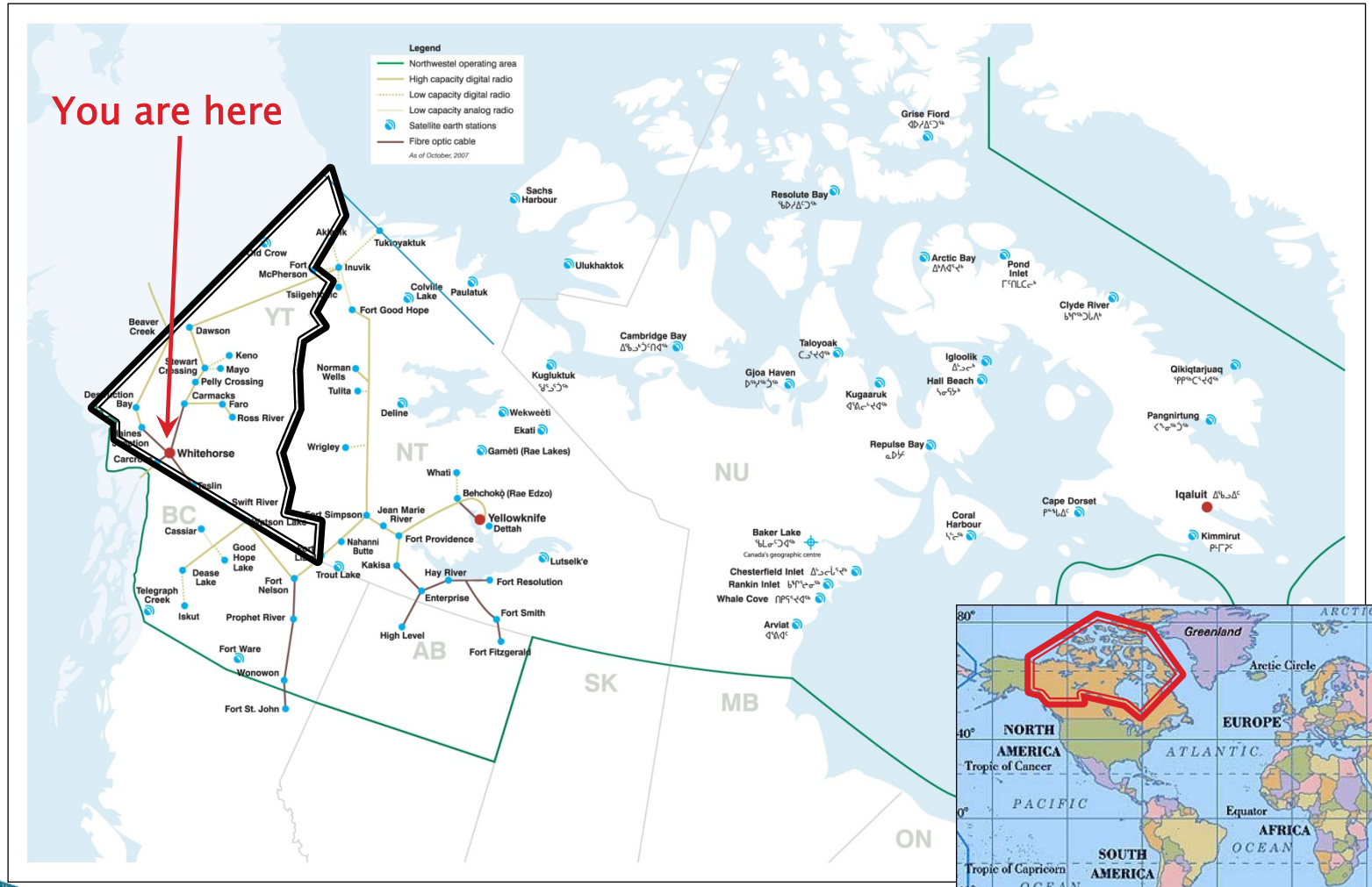
Information Technologies Network Area



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Cycle/Charge Communications Site

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Existing Power Supply

2 x 15 kW Diesel Generators
Age = 40 years
Total Engine Operation Costs = $4/hour

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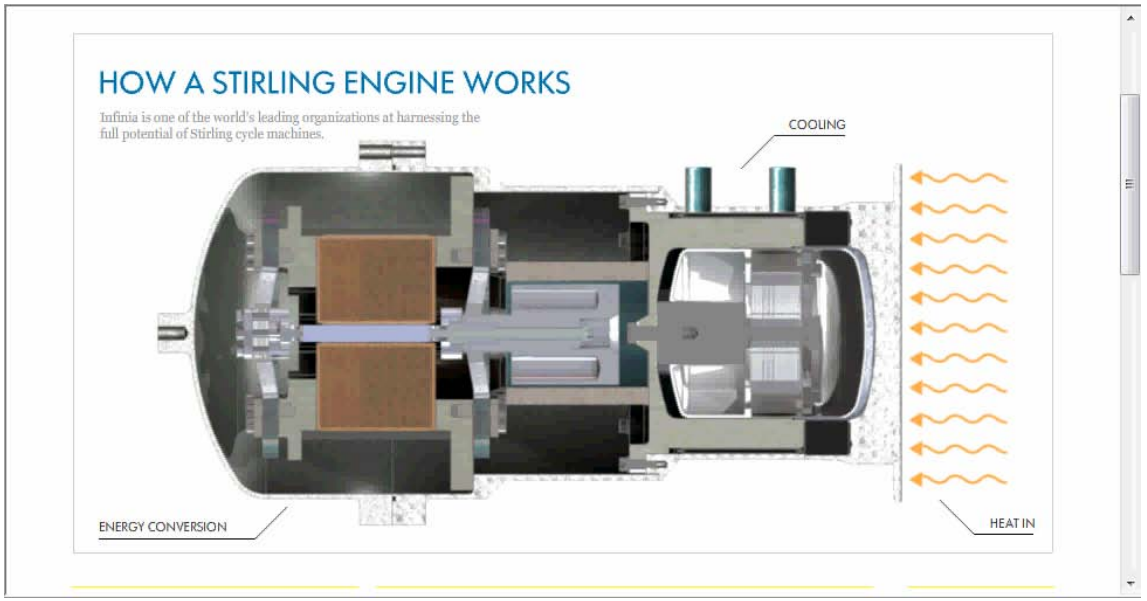
Objective:
Replace Power Supply with Efficient and Durable System

Cold Input



Heat Input

Yukon Cold Climate Innovation Centre

Research/Innovation Playbook

- Identify a compelling economic/infrastructure need
- Identify and bring to ground an appropriate platform technology
  - open source technology
  - scalable and expandable
  - shared risk/reward
  - SCADA telemetry
- Co-develop Highly Qualified Personnel
- Add value to innovations through companion technologies/processes

"Research is the transformation of money to knowledge.
Innovation is the transformation of knowledge to money."

Dr. Hans Meixner.

consulting engineers
& scientists

Integrated Geothermal Assessment, Takhini Hot Springs, Yukon

Takhini Hot Springs Ltd.
Garry Umbrich, President

EBA Engineering Consultants Ltd.
Stephan Klump, Ph.D., Jack Dennett, P.Geo., Ryan Martin, P.Eng.

Takhini Hot Springs (THS)

- Only hot spring in Whitehorse area;
- Has been known for at least a century;
- First development circa 1940;
- Thermal water has been used for bathing and heating;
- Fairly constant temperature of 46.5°C and flow rate of 6.6L/s.

Geothermal Exploration and Development Phased Approach

- Phase 1 – Geothermal Reconnaissance Studies
- Phase 2 – Pre-Feasibility Studies
- Phase 3 – Feasibility and Resource Confirmation Studies
- Phase 4 – Geothermal Resource Development
- Phase 5 – Plant and Infrastructure Design, Installation and Commissioning

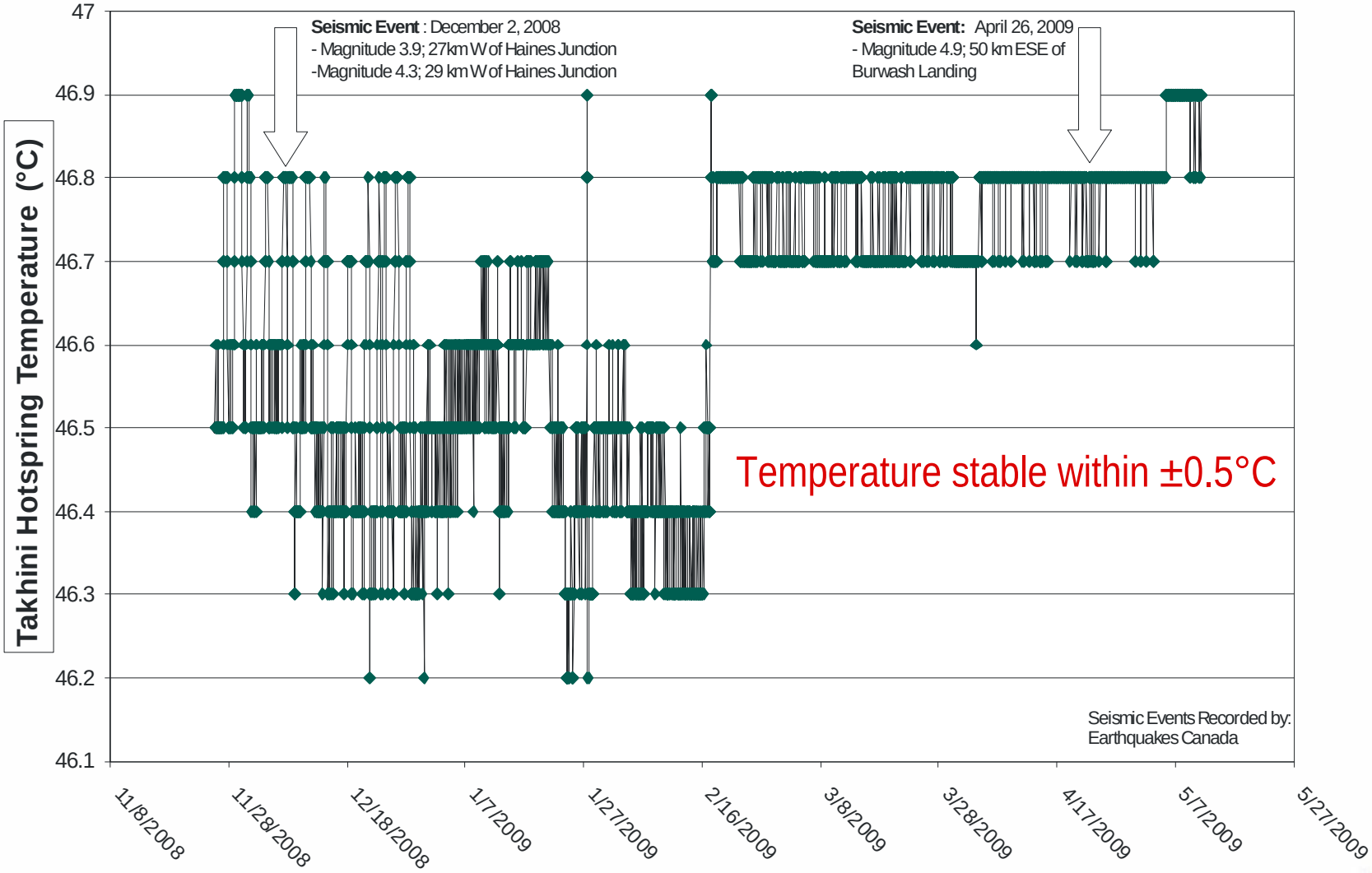
Geothermal Assessment, THS
Phase 1 – Geothermal Reconnaissance Study

- Integrated Geothermal Assessment conducted at THS property in 2008-2009.
- Scope of work included:
  - Continuous temperature measurements;
  - Flow measurements;
  - Water chemistry and geothermometry;
  - Geological mapping;
  - Thermal infrared survey;
  - Assessment of water-use options; and,
  - Development of conceptual geothermal model.

Project Details

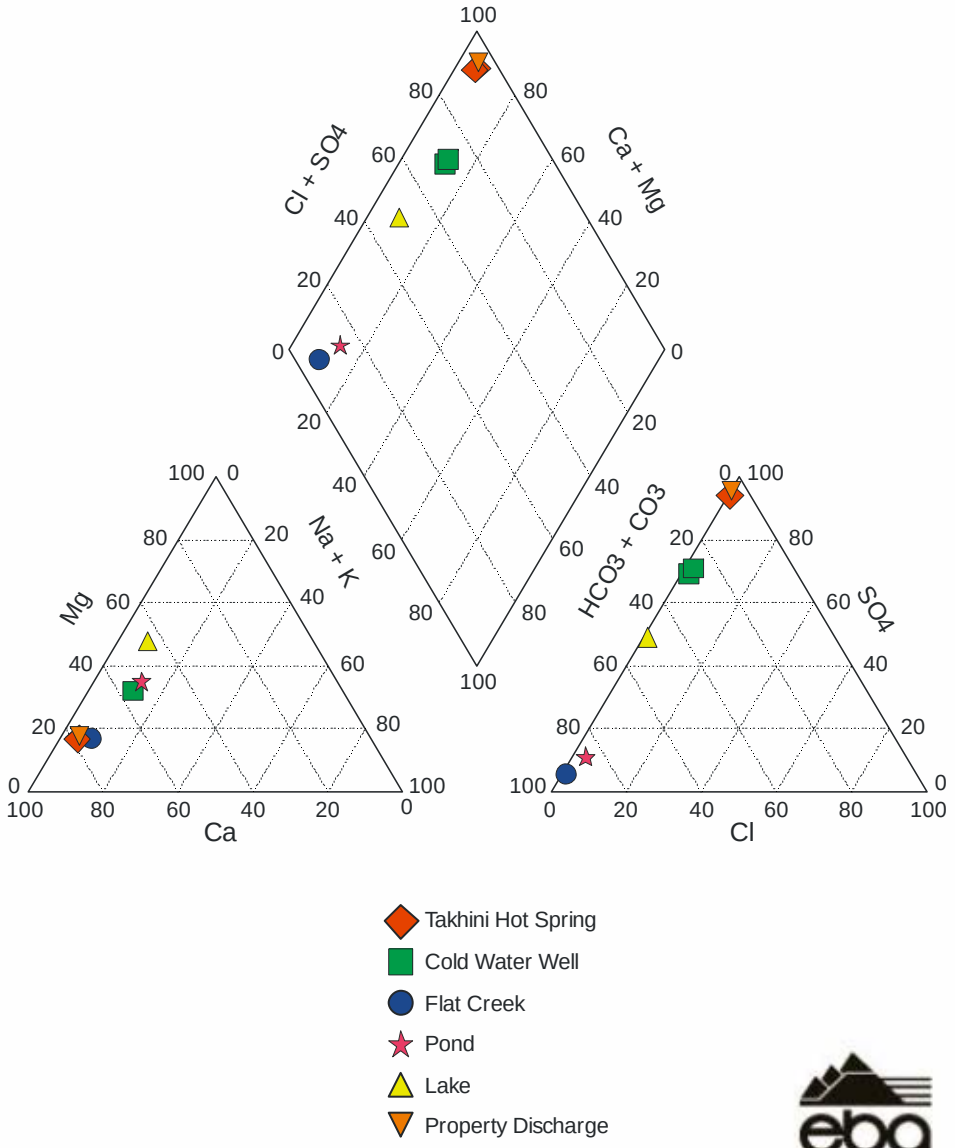
- EBA was retained by Takhini Hot Springs Ltd.
- Study funded by Indian and Northern Affairs Canada;
- Field work completed in Fall 2008 and Spring 2009, Report Issued for Use June 30th, 2009;
- EBA team included several staff to lead the different aspects of the project including Hydrogeologists and Geologists;
- Spectrum Infrared Ltd. conducted thermal infrared survey.

Hot Spring Temperature



Water Chemistry

- Water from hot spring has characteristic chemistry (Ca-SO_4 water type);
- Local surface water and cold groundwater chemistry is different (Ca-HCO_3 and Ca-Mg-SO_4-HCO_3 type water, respectively);
- Hot spring water is <u>not</u> suitable as drinking water (high F, TDS, SO_4, Fe);



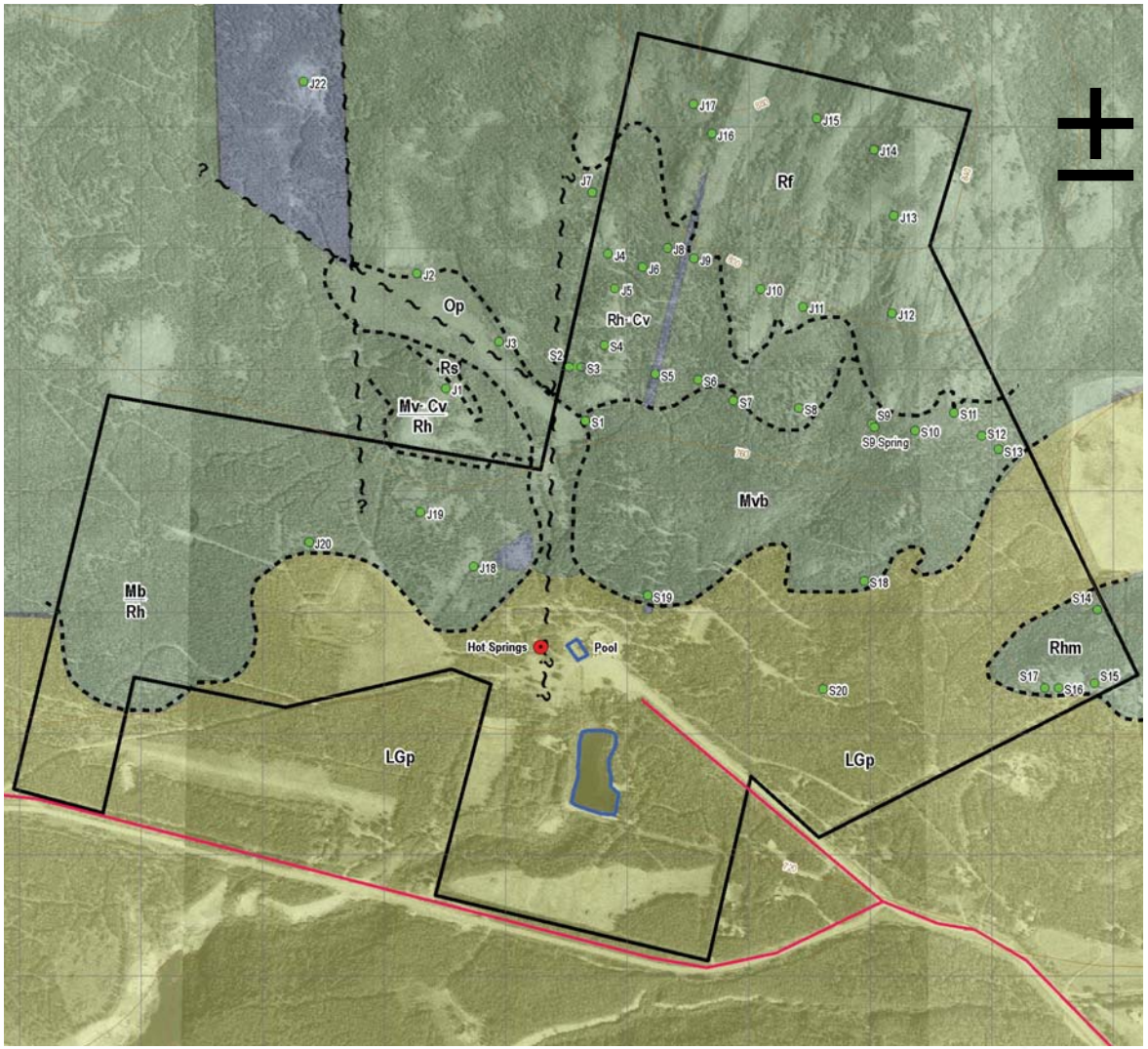
Geothermometry

- Chemical composition and ion ratios of thermal water allows subsurface reservoir temperature to be estimated;
- Assumptions:
  - Dissolved ions in thermal water were in chemical equilibrium with reservoir rocks;
  - Chemical equilibrium is mainly temperature-controlled; and,
  - Fast conduit from reservoir to surface without time for chemical re-equilibration.
- Most common geothermometer methods are based on Na-K-Ca ion ratios and Si concentration;
- Geothermometer temperatures for Takhini Hot Spring:
  - Na-K-Ca: 170°C
  - SiO_2: 96°C

Seems to be more reliable

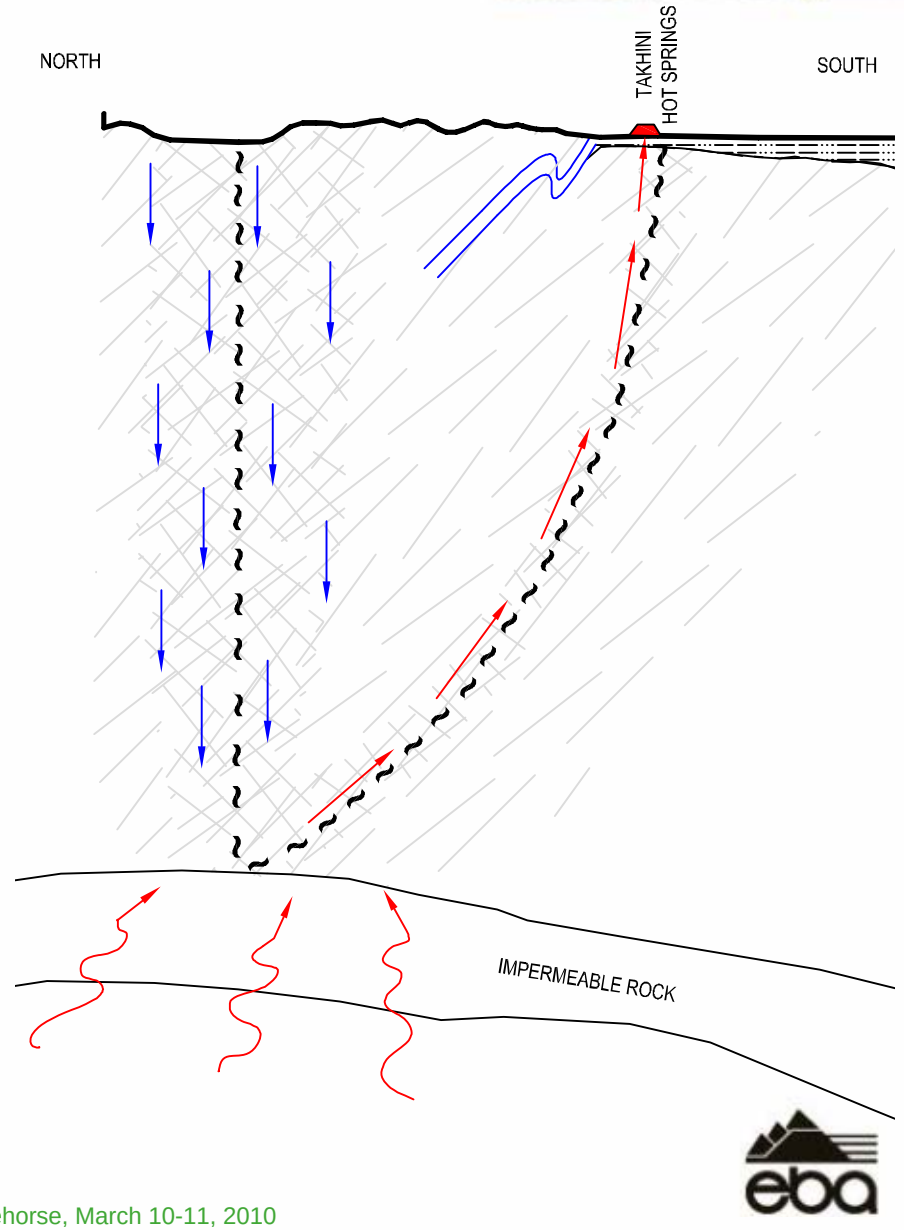
Geological Map

- Southern part of THS property covered by Quaternary sediments
- Northern part is dominated by Upper Triassic sedimentary rocks
- Faults mainly inferred from topography



Conceptual Geothermal Model

- Groundwater percolates to depth through fractured rock;
- Water is heated to about 100°C by shallow heat source or natural geothermal gradient;
- Hot water is “piped” to surface through steep fault, forming the hot spring.



Summary and Possible Next Steps

- Phase 1 assessment focused on surface exploration;
- Little bedrock information in vicinity of hot spring;
- Only drilling provides direct information on geology and subsurface temperature;
- Further site exploration should include:
  - Geophysics to explore subsurface structure;
  - Drilling of thermal gradient hole for direct temperature information;
  - Pre-feasibility and feasibility study for geothermal development.

Engineering Transportation Environment

Mining Development Energy

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