Northeast BC Geological Carbon Capture and Storage Atlas: A Key Step Toward Net Zero Emissions (NTS 093I, O, P, 094A, B, G–J, N–P)

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Introduction

For British Columbia (BC) to reduce carbon emissions and ultimately reach net zero emissions by 2050 (CleanBC, 2018, 2021b), a number of initiatives and technologies have been and must continue to be deployed. Geological carbon capture and storage (CCS) can be utilized to help reduce the level of carbon dioxide (CO_2), a greenhouse gas, in the atmosphere by sequestering CO_2 in the subsurface. Using CCS can also enable low-carbon energy initiatives at surface, including hydrogen production from existing natural gas reserves (CleanBC, 2021a).

A recent study supported by Geoscience BC has identified, assessed, mapped and catalogued the best geological CO_2 sequestration targets and CO_2 storage potential in the area of northeastern BC that is underlain by the Western Canada Sedimentary Basin (Figure 1). The project was designed to

- identify and undertake a preliminary quantification of the storage potential of the best CO_2 sequestration targets in northeastern BC to help enable CCS and low-carbon energy projects, from small to large scale;
- provide key information to enable improved decision making for policy and regulatory makers, and industry;
- recommend future CCS evaluation steps in northeastern BC; and
- provide a template and methodology that can be applied to help assess CO_2 sequestration storage potential in other geological basins in BC, particularly those in proximity to the largest CO_2 emission sites in the province.

The final report for the project, *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023), was released by Geoscience BC in early 2023, along with maps in both PDF and shapefile format, and a fulsome database of oil and gas pool and aquifer data. This paper summarizes the key project activities, outcomes and outputs.

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the Geoscience BC website: http://geosciencebc.com/updates/summary-of-activities/.

Project Overview

The *Northeast BC Geological Carbon Capture and Storage Atlas* published by Geoscience BC is a follow up to the seminal work of Bachu (2006) and was completed in partnership with the B.C. Centre for Innovation & Clean Energy and the BC Hydrogen Office (BC Ministry of Energy, Mines and Low Carbon Innovation). Technical work for the project was undertaken by Canadian Discovery Ltd. Primary goals of the project were to identify the best CO_2 sequestration targets in northeastern BC, and to present the findings in easy-to-use maps and tables.

The study assessed two types of subsurface storage targets: depleted gas pools (i.e., >90% depleted), and deep saline aquifers. The injection of CO_2 into oil pools for enhanced oil recovery was not considered for this project. The study reviewed existing data to filter, assess, rank and map the best CO_2 sequestration candidates for each of 12 subsurface formations (or groups of formations in some cases). Depleted pool data was obtained from the BC Oil and Gas Commission (2021). Aquifer data was largely derived from Geoscience BC Report 2021-14 *Wastewater Disposal in the Maturing Montney Play Fairway of Northeastern British Columbia* (Petrel Robertson Consulting Ltd., 2021) and supplemented by the technical work of Canadian Discovery Ltd.

Pool and aquifer data were vetted for CO_2 storage suitability criteria, including cutoffs for porosity and permeability, and sufficient depth, temperature, pressure and trapping for effective storage. After vetting, 12 subsurface formations were deemed suitable for CO_2 storage. In some cases, equivalent or proximal formations were grouped for ease of mapping and reporting. Storage candidates with initial reservoir pressures greater than 7500 kilopascals and temperatures greater than 31.1°C (the critical point for CO_2) were flagged as having supercritical CO_2 storage potential. At supercritical conditions, CO_2 has high density like a liquid, but low viscosity like a gas—ideal for injection and storage of higher volumes of CO_2 as compared to storage in gaseous phase. Where appropriate, the mapped boundary of gaseous to supercritical phase has been annotated on formation maps.

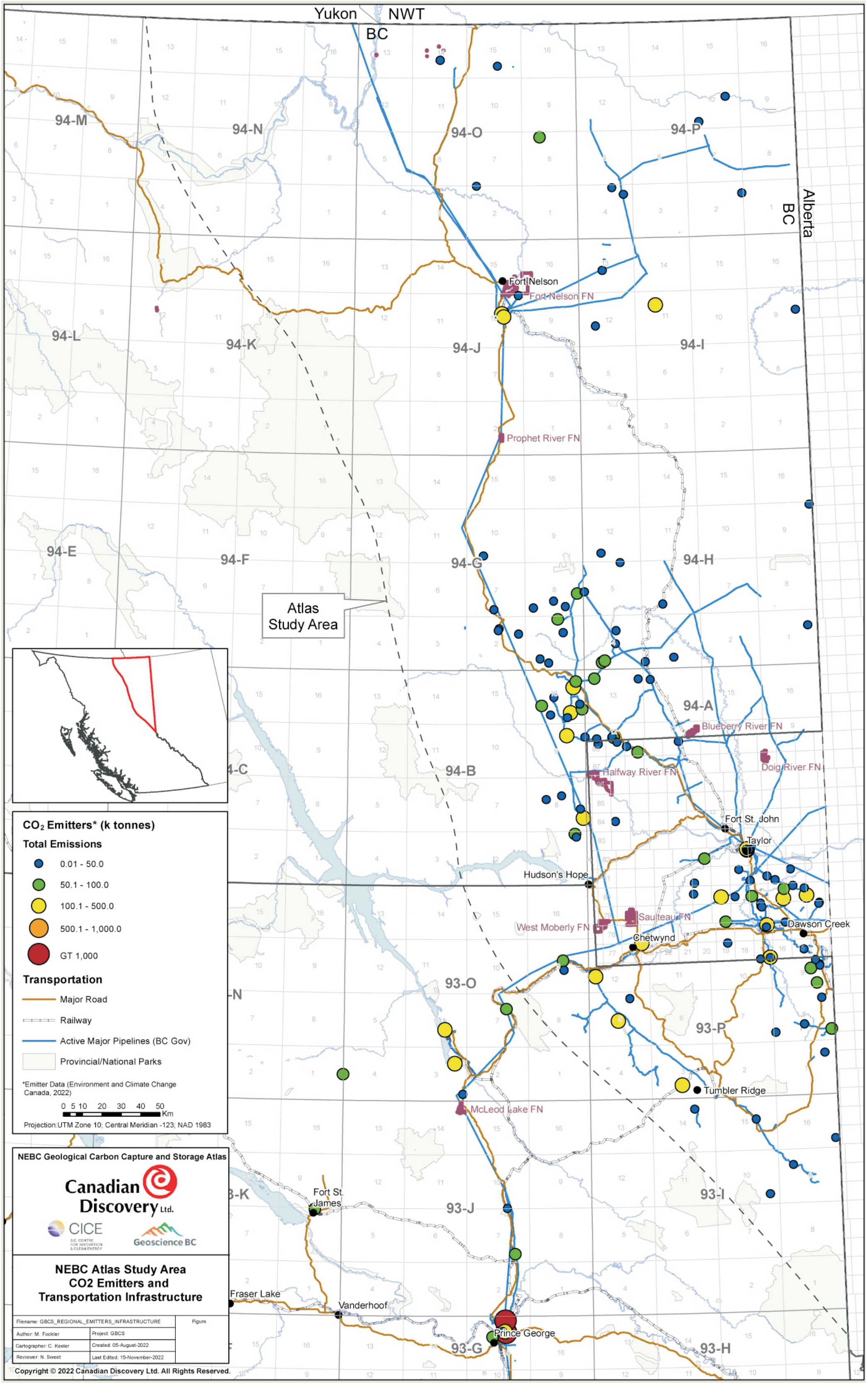

Figure 1. *Northeast BC Geological Carbon Capture and Storage Atlas* project study area. Carbon dioxide (CO_2) emitters are shown as coloured circles, with circle size and colour proportional to annual CO_2 emission volumes. Abbreviations: FN, First Nation(s); Gov, Government; GT, greater than; NEBC, northeastern British Columbia.

Calculations of theoretical and effective CO_2 storage potential for pools and aquifers are provided in the report. Theoretical storage is the mass of CO_2 that can be stored using the reservoir volumes of the produced hydrocarbons for pools, and the mapped pore volume and CO_2 density for aquifers. Effective storage is the storage potential for CO_2 after accounting for various reservoir conditions and fluid properties. Given that terminology varies across jurisdictions, and also changes over time, the term 'storage potential' has been used for this project and is broadly related to the 'storage resources' category of the Society of Petroleum Engineers' storage resources management system (Society of Petroleum Engineers, 2017). The term 'capacity' applies to specific pools or aquifer areas that have undergone extensive storage evaluation, beyond that provided in this study. For regional aquifers, given their large areal extent and that injected CO_2 has to displace fluid in place, the calculations for effective storage potential are provided on a 10^{th} percentile (P10; low), 50^{th} percentile (P50; mean) and 90^{th} percentile (P90; high) basis, as a function of percent of total theoretical storage potential. To determine an estimated effective storage potential for P10, P50 and P90, an E_{saline} or storage efficiency factor was applied to total theoretical storage potential values. The efficiency factor values used were similar to those in the U.S. Department of Energy, National Energy Technology Laboratory's carbon utilization and storage publications (Gray, 2010, 2012, 2015): 0.5% for P10, 2.0% for P50 and 5.4% for P90.

As mentioned, detailed site-specific calculations and modelling is required to define specific CO_2 storage capacity volumes.

Results

The study generated a written report, which provides background information on CCS basics and the methodologies used to vet and calculate theoretical and effective CO_2 storage potential. A stand-alone chapter is provided for each of the 12 formations that have identified storage potential in northeastern BC. Each formation chapter provides summary results, including a brief overview; a table of favourability attributes (Figure 2); a structure map (Figure 3), which also has the gas phase to supercritical boundary annotated; an aquifers and depleted pools effective CO_2 storage potential map (Figure 4); a table of the top 25 depleted pools (ranked by effective storage potential), including metrics for each pool (Table 1); and a table of identified aquifer properties and storage potential, which includes P10, P50 and P90 effective storage potential calculations (Table 2). In addition, more detailed supporting information and mapping is provided in the formation chapters, including a geology summary, net porous isopach map of pools and aquifers, storage and trapping details, porosity-permeability correlations and hydrodynamics.

Belloy Favourability Attributes

Top 10 Depleted Pool Total Capacity	51 Mt	● (green)
Aquifer Storage (P50)	158 Mt	● (green)
Seal Containment Risk	Variable	● (yellow)
Lithology	Dolomitic sandstone	● (green)
Porosity	8-24%	● (green)
Permeability	10-1000mD	● (green)
Depth (TVD)	800-2,900m	● (green)
Net Reservoir Thickness	5-45m	● (green)

Figure 2. Example of table of favourability attributes from the *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023). For each formation, circles indicate whether an attribute is considered generally favourable (green) or has risk and requires additional work (yellow). Abbreviations: Belloy, Belloy Formation; mD, millidarcy; Mt, megatonne; P50, 50^{th} percentile; TVD, true vertical depth.

Importantly, the report includes a map of the total effective CO_2 storage potential calculation of the 'stacked' depleted pools with >5 megatonnes (Mt) of storage potential from all of the 12 formations mapped (Figure 5). As well, there is a similar stacked P50 effective CO_2 storage potential map for all identified aquifer storage areas in the study area (Figure 6). These maps identify areas and fairways of concentrated subsurface storage potential in northeastern BC and are useful in determining future carbon hub and hydrogen hub locations and parameters.

The report includes a chapter that provides detailed references and information regarding CCS, as well as links to BC hydrogen information, and a chapter that outlines recommendations for future research and evaluation work in northeastern BC and how it would be suitable for application to other geological basins in BC for CCS evaluation.

Finally, in addition to the main report, appendices provide supporting information including regional stratigraphy, storage calculations, a digital database for pool data, a digital database for aquifer data, and references and resources for CCS. There are PDF and digital shapefile documents for each suite of maps, all provided by formation in 12 subfolders.

Calculated Effective CO_2 Storage Potential

The project has determined that there are numerous opportunities in northeastern BC for geological CCS in depleted pools and in deep saline aquifers. These sites are appropriate for CCS projects of small to large scale. The total estimated effective CO_2 storage potential of vetted depleted pools is approximately 1200 Mt. The total estimated P50 (mean) effective CO_2 storage potential of deep saline aquifers is approximately 3030 Mt, however, it is noted that aquifer effective storage potential values have a large range,

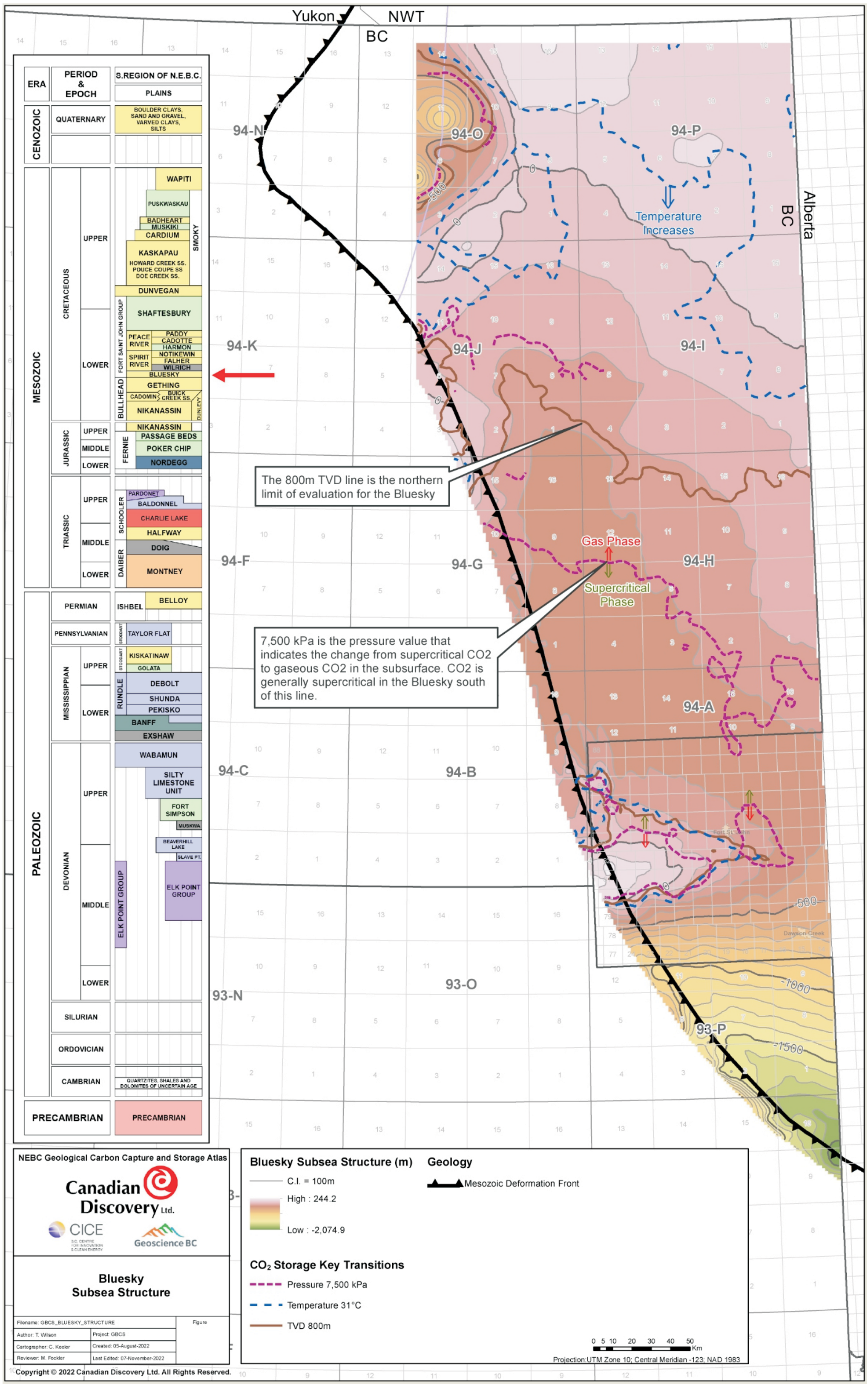

Figure 3. Example of structure map from the *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023). For each formation, lines are annotated for the 800 m depth cutoff, the 31°C cutoff and the supercritical conditions boundary. Stratigraphic column from BC Ministry of Energy, Mines and Low Carbon Innovation (2011). Abbreviations: Bluesky, Bluesky Formation; C.I., contour interval; CO_2, carbon dioxide; kPa, kilopascal; NEBC, northeastern British Columbia; Pt., Point; S., southern; SS, sandstone; TVD, true vertical depth.

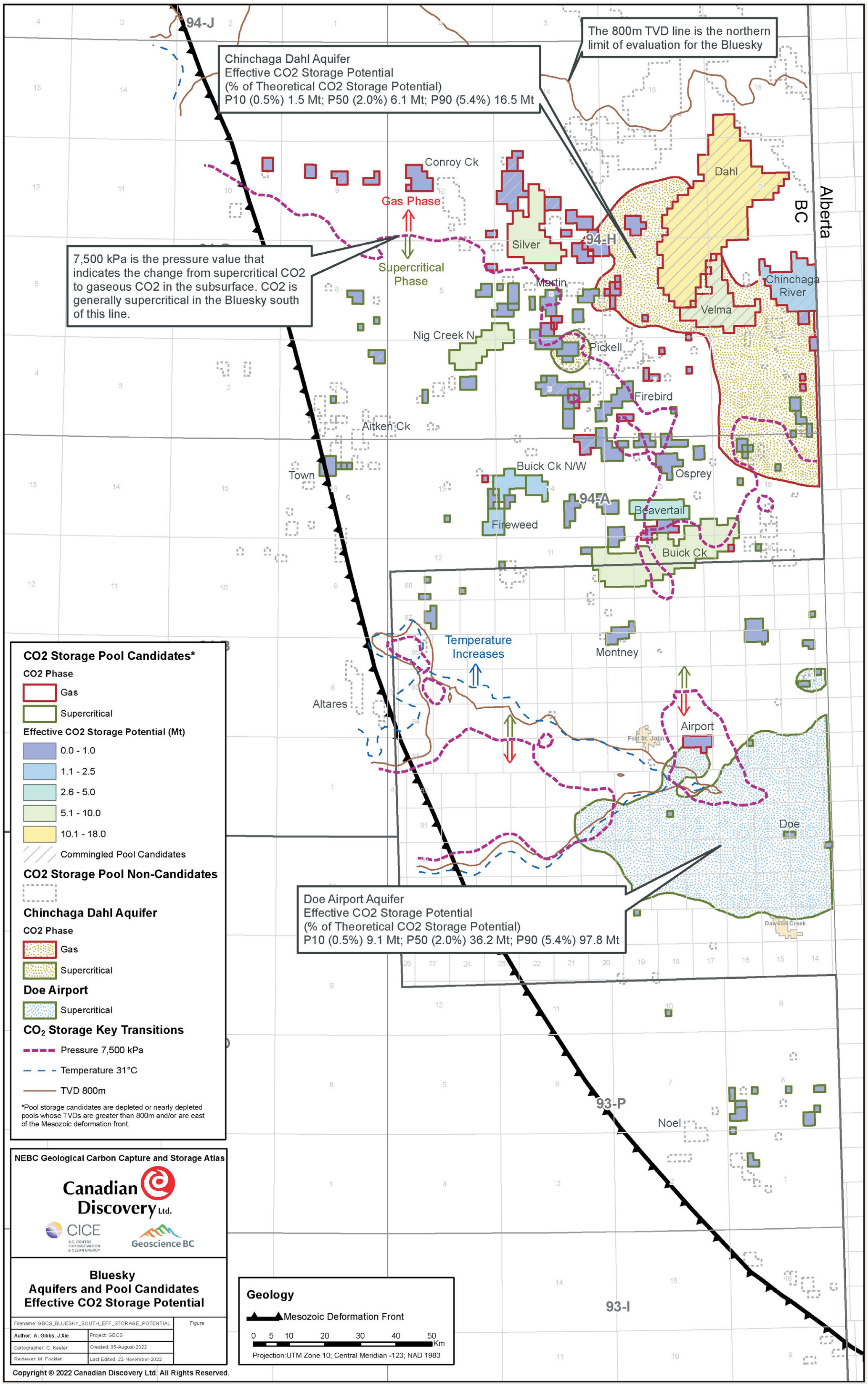

Figure 4. Example of aquifers and depleted pools candidates map from the *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023). For each formation, effective carbon dioxide (CO_2) storage potential is mapped. Abbreviations: Bluesky, Bluesky Formation; Ck, Creek; kPa, kilopascal; Mt, megatonne; N, north; NEBC, northeastern British Columbia; P10, 10th percentile; P50, 50th percentile; P90, 90th percentile; TVD, true vertical depth; W, west.

Table 1. Example of top 25 depleted oil and gas pools table from the *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023). For each formation, key reservoir metrics and carbon dioxide (CO_2) storage potential are provided. Abbreviations: BC, British Columbia; kPa, kilopascal; Mt, megatonne.

Pool name	Pool type	Well count	Initial pressure (kPa)	Temperature (°C)	Average porosity (%)	CO_2 phase	Theoretical CO_2 storage potential (Mt)	Effective CO_2 storage potential (Mt)
Dahl Bluesky Gething-A	Gas	198	6 564	51	15.0	Gas	20.6	18.0
Buick Creek Bluesky C	Gas	130	7 714	48	14.0	Supercritical	11.4	10.0
Nig Creek North Bluesky A	Gas	38	10 332	58	13.7	Supercritical	8.1	7.1
Silver Bluesky A	Gas	37	6 971	59	14.4	Gas	7.6	6.6
Velma Bluesky Gething-A	Gas	41	6 692	53	15.6	Gas	6.1	5.4
Beavertail Bluesky A	Gas	16	7 770	48	12.0	Supercritical	5.1	4.5
Buick Creek West Bluesky A	Gas	12	9 388	54	9.0	Supercritical	2.5	2.1
Buick Creek North Bluesky A	Gas	10	9 080	51	8.9	Supercritical	2.0	1.7
Fireweed Bluesky B	Gas	11	9 062	53	13.5	Supercritical	1.9	1.6
Chinchaga River Bluesky Gething-Detrital-A	Gas	116	6 549	48	17.3	Gas	2.4	1.5
Osprey Bluesky A	Gas	10	7 475	49	12.8	Supercritical	1.1	0.9
Pickell Bluesky Gething-A	Gas	16	7 957	51	11.2	Supercritical	1.0	0.8
Montney Bluesky A	Gas	7	8 715	49	13.7	Supercritical	0.9	0.8
Conroy Creek Bluesky A	Gas	11	5 626	60	15.2	Gas	0.9	0.8
Noel Basal Bluesky B	Gas	2	24 155	77	6.5	Supercritical	0.9	0.8
Fireweed Bluesky A	Gas	4	9 168	53	10.4	Supercritical	0.9	0.8
Tommy Lakes Bluesky A	Gas	6	5 575	56	13.5	Gas	0.8	0.7
Firebird Bluesky A	Gas	13	7 699	53	14.7	Supercritical	1.0	0.6
Martin Bluesky A	Gas	7	8 215	60	16.6	Supercritical	0.7	0.6
Siphon East Bluesky A	Gas	11	8 025	49	14.6	Supercritical	2.3	0.6
Ladyfern Bluesky M	Gas	3	7 449	43	19.4	Supercritical	0.8	0.5
Buick Creek Bluesky A	Gas	6	7 660	48	10.8	Supercritical	0.5	0.5
Noel Basal Bluesky J	Gas	2	28 268	86	8.1	Supercritical	0.5	0.5
Nig Creek Bluesky C	Gas	6	10 199	61	11.4	Supercritical	0.7	0.4
Town Bluesky D	Gas	9	10 392	60	13.0	Supercritical	0.5	0.4

Table 2. Example of aquifer properties and storage potential table from the *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023). For each formation, key aquifer reservoir metrics and effective carbon dioxide (CO_2) storage potential on a 10th percentile (P10; low), 50th percentile (P50; mean) and 90th percentile (P90; high) basis are provided. Abbreviations: BC, British Columbia; MPa, megapascal; Mt, megatonne.

Aquifer name	Type	Thickness range (m)	Pressure range (MPa)	Temperature range (°C)	Porosity range (%)	CO_2 phase	P10 effective storage potential at 0.5% (Mt)	P50 effective storage potential at 2.0% (Mt)	P90 effective storage potential at 5.4% (Mt)
Chinchaga-Dahl Regional System	Aquifer	2–10	5.7–7.9	43–60	9–21	Mostly gas	1.5	6.1	16.5
Doe-Airport Regional System	Aquifer	2–40	6.6–11.1	27–56	8–22	Mostly supercritical	9.1	36.2	97.8

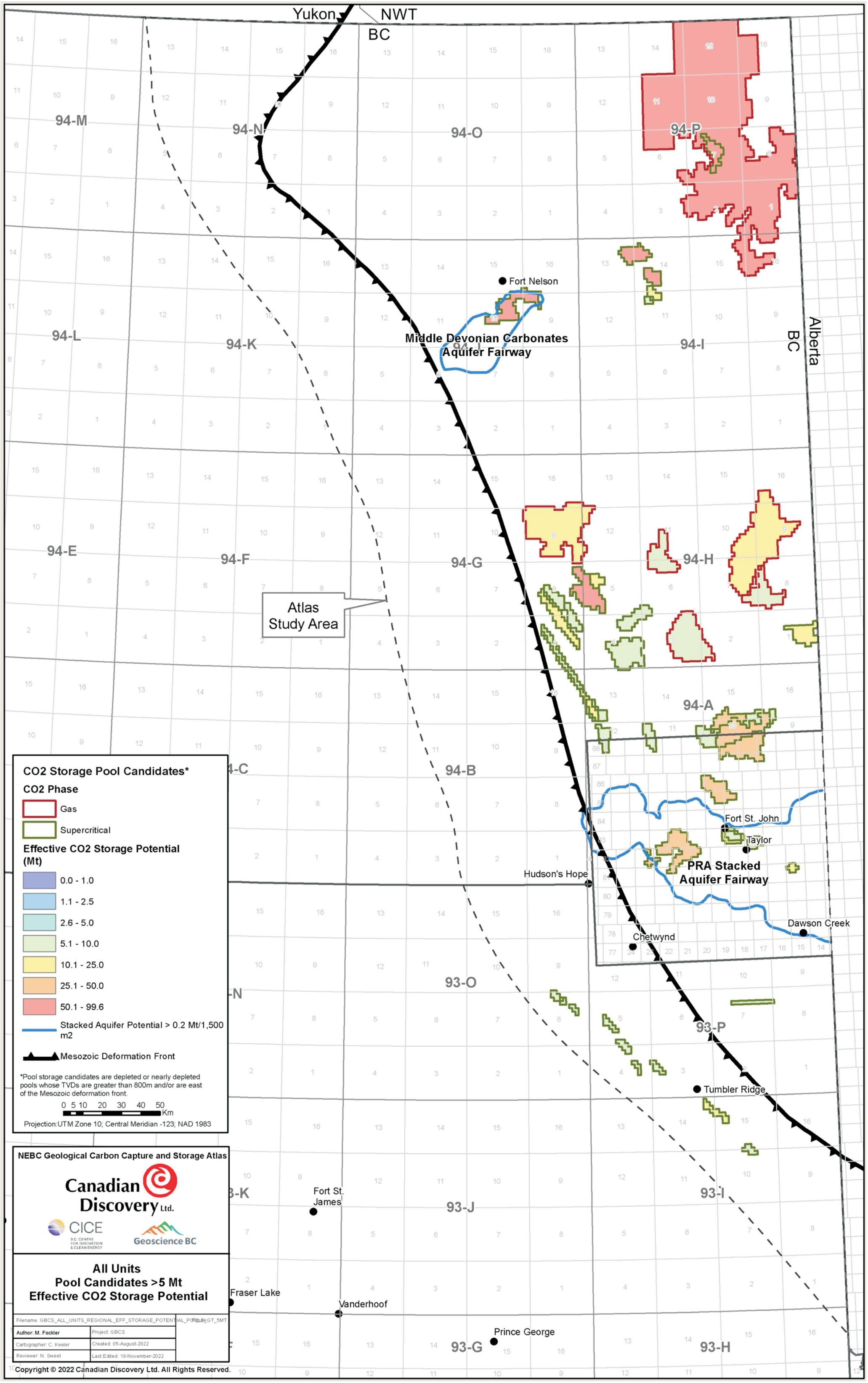

Figure 5. Depleted pools with greater than 5 megatonnes (Mt) of effective carbon dioxide (CO_2) storage potential in northeastern British Columbia. This is a summary map that combines the largest pools from all 12 formations mapped (reproduced from Canadian Discovery Ltd., 2023). Stacked aquifer fairways are also annotated on the map. Abbreviations: GT, greater than; Mt, megatonne; NEBC, northeastern British Columbia; PRA, Peace River Arch; TVD, true vertical depth.

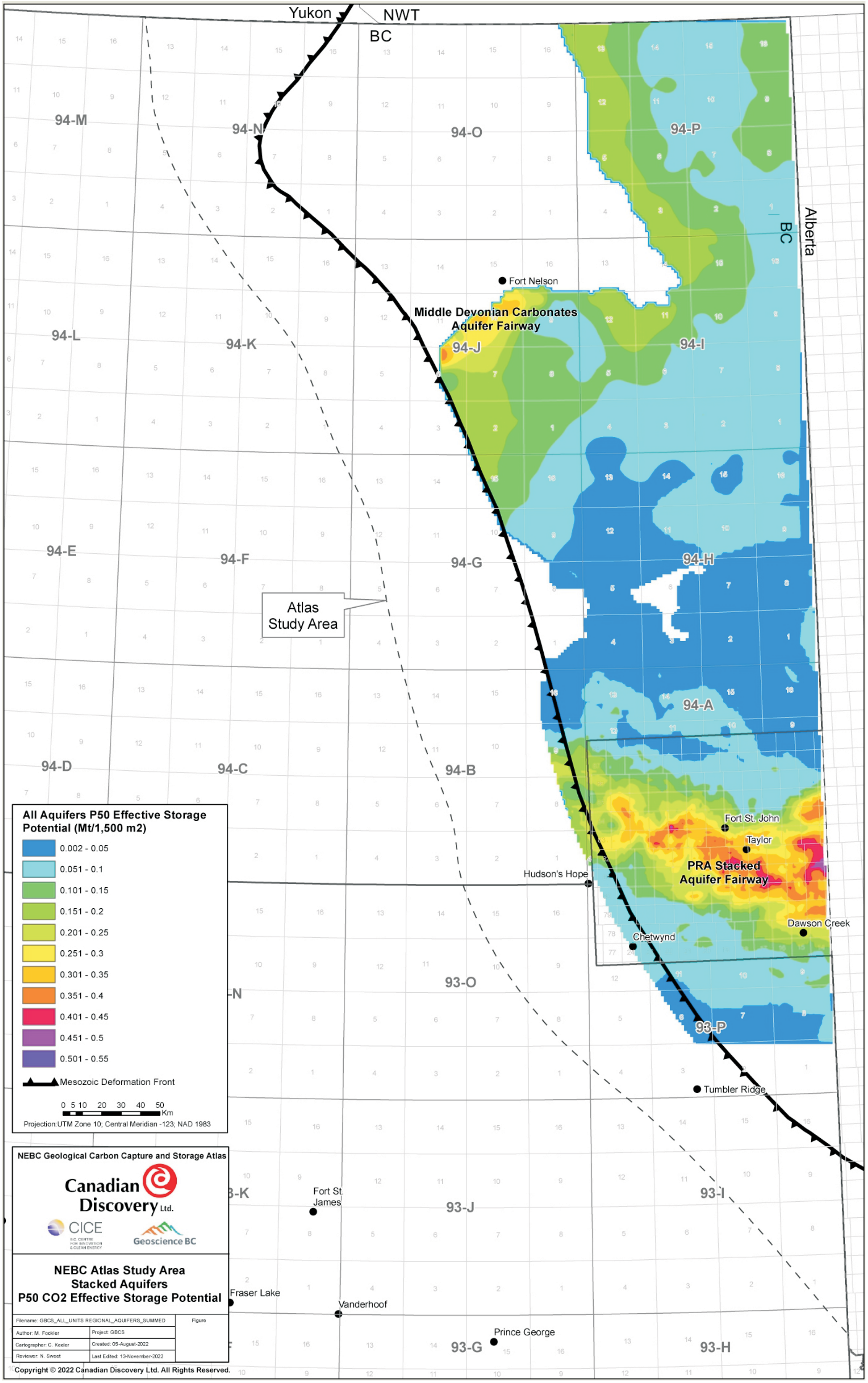

Figure 6. Total estimated effective carbon dioxide (CO_2) storage potential of stacked aquifers (for 50th percentile; P50) in northeastern British Columbia. This is a summary map that combines the aquifer storage potential from all 12 formations mapped (reproduced from Canadian Discovery Ltd., 2023). Note that not all formations have storage aquifers available. Abbreviations: Mt, megatonne; NEBC, northeastern British Columbia; PRA, Peace River Arch.

from 758 to 8182 Mt. Combined, the total depleted pool and P50 aquifer effective CO_2 storage potential is approximately 4230 Mt.

For depleted pools, CCS favourable storage fairways have been identified in the region north and northeast of Fort St. John, and in the northeastern corner of the study area (Figure 5). For aquifers, CCS favourable storage fairways have been identified in the Dawson Creek to Fort St. John region and south of Fort Nelson (Figure 6).

It is noted that defining site-specific CO_2 sequestration capacities will require considerable additional investigation and detailed modelling.

Conclusions

The *Northeast BC Geological Carbon Capture and Storage Atlas* provides a summary of the best geological carbon dioxide (CO_2) sequestration sites in northeastern British Columbia, in depleted gas pools and in deep saline aquifers. Total calculated effective CO_2 storage potential, including 50th percentile calculations for aquifers, is greater than 4000 megatonnes in the study area, which is enough storage potential to consider carbon hub or hydrogen hub development. Strategic areas of carbon capture and storage potential have been identified as storage fairways.

The study report and associated maps provide data in easy-to-use summary format, but also provide more detailed supporting information and databases. The study provides a key dataset that identifies the best zones and areas for carbon capture and storage and low-carbon hydrogen development, but recognizes that additional detailed research and work is required in northeastern British Columbia before reaching development decisions, particularly for carbon hub or hydrogen hub development.

The study provides information that can help guide regulations and policies, and is a template for evaluation of other geological basins in British Columbia.

Acknowledgments

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